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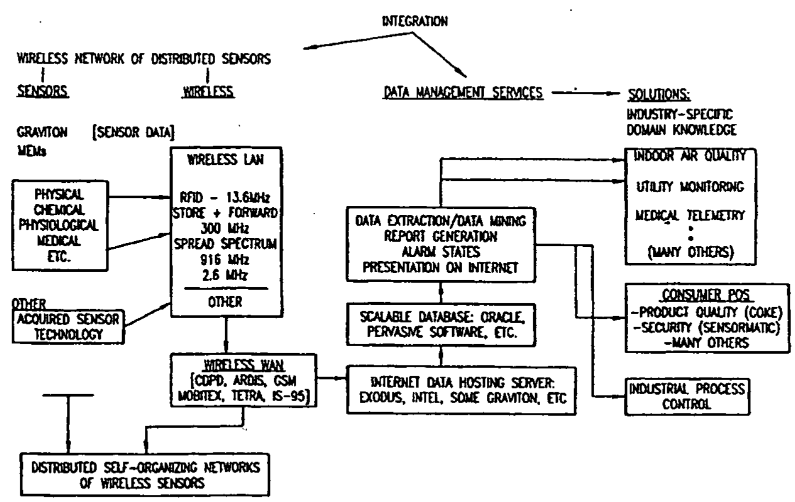

(57) Abstract

Systems, architectures and methods of operation and use of remotely spaced sensors (50) are provided. Networks (28) and component arrangements of sensors (50), actuators (90), and networks provide the collection, analysis and action upon sensed information at multiple remote locations. In the preferred embodiment, sensors such as microcantilever sensors or microelectromechanical systems (MEMS) are connected via a network, such as the Internet to provide effective operation of the sensor network (28). In one aspect of the analog to digital converter (56), communicate through an interface or thin server to the Internet, communicating with an end user/processor (110). Sensor assemblies (50) are provided which typically include multiple sensors (52), such as for the sensing of various environmental or process conditions or stimuli. Optionally analog electronics (54), such as to aid in signal detection of processing, analog to digital converters (56), and a network connection (42).

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SYSTEMS AND METHODS FOR NETWORK BASED SENSING AND DISTRIBUTED SENSOR, DATA AND MEMORY MANAGEMENT

Field of the Invention

The inventions described and claimed herein relate generally to systems and methods for sensing or monitoring at one or more remote locations. More particularly, they relate to systems and methods for distributed, remote sensing at multiple locations utilizing a network based interconnection for data analysis and management. In yet another aspect, they relate to self-organizing sensor networks and machine-to-machine communications.

Background of the Invention

Various efforts have been made to develop sensors and detectors for various conditions. Sensors have been developed, and will continue to be developed, which measure a large number of physical or non-physical phenomenon. Generally, such sensors may be described as a device which receives some external stimuli or as otherwise influenced by a physical phenomenon, which through the use of some transducer generates a signal related to or corresponding to the stimuli or condition, which signal is then utilized in further processing or analysis of the phenomenon or condition. By way of example, sensors are used to detect a wide variety of physical phenomenon, chemical presence or biochemical material presence. More particularly, such sensors may measure relative humidity, temperature, pressure, flow, viscosity, sound, optical data, chemical or biological presence or radiation.

One type of sensor known to the art are formed as microcantilevers beams, similar to those developed for atomic force microscopes. Such microcantilever sensors have been demonstrated as platforms for real-time, *in situ* measurement of physical, chemical and biological properties. See, e.g., Thundat, T., *et al.*, "NanoSensor Array Chips,

Microcantilever Arrays Serve as a Universal Sensor Platform", Appliance Manufacturer, April, 1997, p. 57-58, Baselt, David R., et al., "A High-Sensitivity Micromachine Biosensor", Proceedings of the IEEE, Vol. 85, no. 4, April 1997, p. 672-680. Fig. 1 is a cross-sectional view of a typical capacitive microcantilever system. A substrate 10 supports a cantilever 12 on a pedestal 14. A base plate 18 serves as the second plate to a capacitor formed in part by the cantilever 12, a conductor 16 serves to couple electrical signals to and from the microcantilever. In certain implementations, a single-crystal silicon substrate 10 may include a conductive region, such as formed by a boron-doped surface layer. The resistance changes resulting from cantilever deflection may then be detected. In yet other implementations, the deflection of the cantilever 12 may be achieved through optical means, such as by illumination by a laser, such as a diode laser. The detection of the bending motion of the cantilever is determined by measurement of reflected light. In other implementations, a cantilever can be made of known piezoresistive material of which an electrical signal is generated when the cantilever bends. Further structures and applications of devices may be found in the following United States patents: Burnham et al., U.S. Patent No. 5,193,383, "Mechanical and Surface Force Nanoprobe", Colton et al., U.S. Patent No. 5,372,930, "Sensor for Ultra-Low Concentration Molecular Recognition", Wachter et al., U.S. Patent No. 5,445,008, "Microbar Sensor", and Wachter et al., U.S. Patent No. 5,719,324, "Microcantilever Sensor", all incorporated herein by reference as if fully set forth herein.

Efforts have been made to provide communication capability between a sensor and a user of information. Telemetry from a sensor unit has been described in the Thundat article in Appliance Manufacturer, April, 1997, pp. 57-58. The article contemplates the use of telemetry to enable the use of mobile units worn or carried by personnel, the deployment of such devices relaying pertinent data to a central collection station, and suggesting the possibility of replacing wired sensors in some applications. Yet others have suggested arrangements of an Internet network force feedback system which includes a server machine, a client machine provided with a force feedback device and one or more additional client machines which may be provided with additional force feedback devices. Such a system is disclosed in WO98/06024, Rosenberg et al., "Method and Apparatus for Providing Force Feedback Over a Computer Network". Yet others have suggested the use of an interactive intervention training system used for monitoring a patient suffering from

neurological disorders. Such a system disclosed in U.S. Patent No. 5,810,747, entitled "Remote Site Medical Intervention System", utilizes a communication system of a LAN or the Internet to communicate with various stations, such as supervisor stations and patient/trainee stations. Others have suggested forming implantable biosensing transponders, such as in Kovacs et al., U.S. Patent No. 5,833,603. There, a biosensing transponder for implantation in an organism includes a biosensor for sensing one or more physical properties, including optical, mechanical, chemically and electrochemical properties, and providing a transponder for wirelessly transmitting data corresponding to the sensed parameter value to a remote reader. In yet another disclosure, a medical ultrasonic diagnostic imaging system is provided which communicates images over a system, such as the world-wide web, to a physician or other at a remote location. See, e.g., Wood et al., U.S. Patent No. 5,715,823.

Yet others have used networks to monitor the status of apparatus or appliances. Various machines, such as canned soft drink dispensing machines (e.g., Coke machines) have been connected to the world-wide web for remote monitoring or interaction. One example of such a system is described in Lloyd's Coke Machine at http://www.ugcs.caltech.edu/~walterfb/coke/coke.html. The system described there may determine the number of units in stock, that information being sent via serial cable to a linux machine. Yet other systems exist for providing a bus arrangement to which various devices may be interconnected. For example, the Dallas semiconductor one-wire bus utilizes an Ethernet standard to communicate, and from the bus, various devices may be attached. To date, no completely satisfactory solution in the use of communication systems to sense and/or control remote devices or appliances has been presented. This deficiency is particularly exacerbated when a relatively large number of appliances for sensors is included. The invention disclosed, below, seek to remedy those deficiencies.

Summary of the Invention

The systems and methods described herein permit effective use of remotely spaced sensors and detectors, or embedded networks of sensors and detectors. More particularly, networks and component arrangement of sensors, actuators and networks are described which permit the collection, analysis and action upon information sensed at the remote locations, or embedded within larger appliances or machines. In one aspect of this invention, a system provides for a self-organizing sensor network. Self-organization occurs when various component devices, such as a sensor or a node, effectively communicate with other component devices (machine to machine communications) for the purpose of determining the presence of other component devices, determining communication requirements or otherwise serving to provide networking or collaborative action between various component devices. The component devices themselves, as opposed to essentially command-and-control systems, serve to organize at least a portion of the overall network.

In one aspect of the invention, a system is provided for the remote sensing of those parameters at a first location remotely separated from a second location, such as an end user location, by a communications network. In the preferred embodiment, the remote sensor includes at least one digital (or analog) sensor or detector, the digital sensor serving to sense the parameter at the first location and to output a digital signal indicative of that parameter. The digital sensor or detector may optionally comprise an analog sensor which generates a signal indicative of the parameter and an analog digital conversion system to receive the output of the analog system and provide a digital output signal representative of the sensed parameter. Optionally, analog electronics serve to interconnect the analog sensor and the analog to digital converter. The digital sensor includes a coupling for interconnection of the digital sensor to the communication network, which can be, for example, cabled, telephone line, or wireless transmission. For example, a network connection serving to couple the digital signal to a network, such as the Internet may be provided. A processor coupled to the communication network at a second location serves to receive the digital information from the digital sensor as passed through the communications network.

In the preferred embodiment, the sensor assembly containing the digital sensor includes a processor. Such a processor may comprise a microprocessor and associated

components including memory (RAM, ROM, mass storage, Flash, optical memory, Biomemory, etc.) and supporting components (e.g., clock, bus). Additionally, the processor may be particularly adapted for use with a network, especially the Internet, and may comprise, for example, a NETsilicon Inc. NET+ARM™ processor, a TiniJ processor, or a similar network-enabled microprocessor; may be programmed using a high-level programming language such as Java; and may incorporate and network-related software technologies such as Jini. The inclusion of processing at the sensor assembly results in a 'smart' sensor assembly. Such distributed intelligence aids in the effective utilization of large numbers (substantially 100 or more, or more preferably, 1,000 or more) sensors though the inventions may be practiced with one or more sensors or detectors, e.g., 1, 10 or more sensors. To yet further enhance the processing of data, especially in systems with a large number of sensors, neural networks and/or fuzzy logic software or systems may be employed. This capability would typically reside in data management capability, though it may be done in a distributed manner.

The sensor assembly may be compliant with smart sensor communication standards such as IEEE 1391.1, 1391.2, 1391.3, and/or 1391.4.

In systems having a large number of remote sensors, nodes or node processors are utilized in conjunction with groups of one or more sensor assemblies for the effective utilization of the sensors (clustering). Such a node may comprise a processor, such as a NET+ARM or TiniJ processor (possibly running a Java virtual machine and a software "agent" technology such as Sun Microsystem's Jini), plus associated support peripheral components (memory, RAM, ROM, mass storage, flash, etc.), and a network connection. In one architecture, the system is provided for sensing parameters at a plurality of remotely spaced locations, those locations being interconnected by a network, preferably the Internet (but also LAN or WAN networks, such as Ethernet or ATM, hyperlan, or Ultra-wideband networks), having multiple sensor-node clusters. The sensor-node clusters include a plurality of sensor assemblies, and at least one node; and the plurality of sensor assemblies are adapted for communication with the node. By associating multiple sensor assemblies with the node, one option would be that processing of data may be performed remotely, without the need to communication with a server or end user. Such an arrangement reduces the amount of data to be transmitted as compared to systems having only communication from a sensor assembly to an end user, and in particular eliminates

communication bottlenecks that might occur at a central server. Further, such an architecture minimizes the amount of processing required at the server or end user location (i.e., eliminates processing bottlenecks). Optionally, the sensor-node cluster includes one or more actuators for providing location action.

In yet another advantageous architecture, various sensor-node clusters are provided additional nodes. Such a system for sensing parameters at a plurality of remotely separate locations may include one or more sensor-node clusters, and one or more additional nodes. Each additional node is coupled to some, but not necessarily all, sensor assemblies in one or more sensor-node clusters. The various sensor-node clusters and the additional node are interconnected by a communication system, such as a network, i.e. an Internet, a LAN, or a WAN, hyperlan, or Ultra wide band network. Thus, for example, one sensor-node cluster may be provided for each room in a building, and an additional node may be provided to monitor all temperature sensors in the building.

In more extensive sensor systems, more than one level of node processor may be provided. Secondary nodes may, for example, be connected to the primary nodes within sensor-node clusters. Such secondary nodes serve to further reduce the data from primary nodes, and in general a sensor system will contain fewer secondary nodes than primary nodes. Furthermore, tertiary nodes may be connected to secondary nodes, and so on.

The systems and methods of the invention optionally include actuator assemblies. An actuator assembly optionally includes one or more actuators which are operatively coupled to receive control signals or commands. The actuator commands may be received via the network, e.g., the Internet, from the end user, a node, or another sensor assembly, or may be generated at the actuator assembly such as through a processor. In the event that the control signals are digital, and the actuator requires analog control signals, a digital to analog converter would be disposed between the source of the digital signals and actuator. The actuator assembly typically includes a network connection, such as would communicate with the processor, if utilized, or with the actuator. Optionally, the actuator assembly may include one or more sensors and associated structures, such as an analog to digital converter.

The systems, methods and architectures of these inventions may be utilized with a wide variety of sensors or detectors that measure chemical, biochemical, and/or physical parameters. Various types of sensing mechanisms contemplated include: electric field

sensors (e.g., capacitive biosensors, chemFETs, or microcantilever sensors), magnetic sensors (microbalance, microcantilever, magnetoresistive, or SQUID sensors), optical sensors (e.g., photo responsive electrodes, CCD arrays, optical cameras), acoustic wave sensors (e.g., surface plasmon resonance sensors, surface acoustic wave sensors), chemical sensors (e.g., chemFET, MOSFET, electrochemical, metal-oxide semiconductor film sensors), spectrometric sensors (e.g., UV, visible or spectrasensors, surface enhanced RAMAN scattering sensors, gas chromatograph/mass spectrometry), thermal sensors (e.g., thermoresistors, thermistors, thermocouples, thermopiles, calorithermic cantilevers), physical sensors such as flow meters, pressure sensors, acceleration sensors, etc. or standard Tin-oxide sensors Optionally, multiple sensors may be included within a single sensor assembly, for example, a multiple cantilever chip, having e.g., 10 or more sensors, may be utilized. The output of the various sensors may then be combined for analysis and identification of the environmental condition. The items sensed may include chemicals (e.g., CO, NH_3, CO_2, H_2S, CO_2, H_2S, CO_2, H, etc.), explosives (e.g., TNT), metals (e.g., mercury), organics (e.g., volatile organics, propane, methane), humidity (e.g., water vapor). Biological materials may be sensed (e.g., DNA, RNA, antibodies, proteins, enzymes, antigens, bacteria, etc.). Electromagnetic radiation can be sensed (e.g., light, infrared, microwave). Physical parameters may be sensed (e.g., pressure, flow, temperature, optical data, viscosity, turbidity and acceleration (linear and/or angular)). The form of detected material may be any suitable for detection, whether gas, liquid or solid (such as particulate matter). In one aspect of this invention, multiple sensors may be included within a given sense or assembly. Some or all sensors may be redundant sensors. Alternatively, various sensors may sense different parameters or conditions on the same platform, such as temperature and gas, or aromatics and temperature.

Various methods are advantageously utilized with the systems and architectures of these inventions. For example, a method for sensing a plurality of parameters at a large number (e.g., substantially 100 or more) remote locations where each remote location includes one sensor assembly, and further the sensor assembly as having nodes associated therewith, the method may comprise the steps of sensing the parameters at the remote locations, storing the data at each of the remote locations, generating statistical data from the sensed data, checking for instructions from a node, and in the event that an instruction is received, responding to the instruction, and at a predetermined time, sending the

statistical data to the node. In this way, large amounts of data may be obtained, processed and utilized in a system having a large number of remotely located sensors.

The inventions described and claimed herein include a computer program embodied on a computer readable medium for controlling, processing and use of sensed data signals relating to environmental parameters. More particularly, it comprises a sensor assembly source code segment comprising code for the receipt, and storage of signals corresponding to said data signals, a network communication source code segment for communication of information from the sensor assembly to a network and from a network to the sensor assembly, and a processor source code segment associated with a processor remote from said sensor assembly, and operatively coupled to the network. Similarly, a computer data signal embodied in a carrier wave is provided for the same purposes and functionalities.

In one implementation, the invention consists of a data management service or business method. The method consists of at least the steps of receiving information, preferably information having been derived from various nodes or sensors. Next, the information is processed. Thirdly, the processed information is responded to, either by responding back to the sensors or other component devices, e.g. an actuator, relating to the original sensed event, or providing information, such as notification or other reports, to a customer or client. Optionally, the system may utilize data extraction and/or data mining techniques. Various forms of communication from the system to the customer or client may be utilized, such as internet access of the information contained within the data management system, communication from the system to the customer, such as by report generation or electronic communication, e.g., email, telephone communication, facsimile, pagers or beepers, or any other mode of communication to the customers or client. One application for the data management service methodology includes inventory management services.

In one application, the systems, architecture and methods of these inventions are utilized in a remote food sensing application embedded within pre-existing machinery. Large institutional distributors of a given food product desire to maintain an even quality throughout a large geographic area. For example, a soft drink manufacturer who sells through soda fountains may desire to ensure an even quality of delivered products in locations around the globe. The distributor desires control, consistency and accuracy of

delivered products, and also the volume amounts of products distributed. Sensors may be utilized to monitor the quality of ingredients, such as water quality sensors, chemical sensors (e.g., to monitor CO_2 levels), sugar content, ion content, viscosity, and temperature. Further, sensors may be utilized to detect the presence of contaminants, such as biological contaminants. Further, physical parameters may be sensed, such as pressures, temperature, flow rate, viscosity and density. Further, sensors may be provided to monitor for erroneous product delivery, such as where the system is designed to deliver a diet soft drink, but rather, a regular soft drink is erroneously supplied, or where a decaffeinated product is desired, but a caffeinated product is delivered. In operation, the sensor clusters monitor the various components as they pass the sensor. In certain instances, physical contact between the components and the sensors is required, such as where detection of flow rate or viscosity is desired. In other instances, volatile compounds may be monitored through an electronic 'node', such an arrangement avoiding contact with the food. In one implementation, a closed loop system may be provided whereby the sensed data is utilized by a control system to activate an actuator, such as where a recipe is changed or modified based upon available ingredient quality. Alternatively, the data may be provided to other entities for use, such as an end user who may seek to monitor the quality worldwide.

Yet other applications for the systems, architecture and methods include vending machine status. In operation, information relating to the operating status of the machine, such as temperature, inventory, availability of money for change, and power consumption, may be monitored. The machine may be queried from a processor,.either an end user or a node processor, or a integrated processor, such as through the polling of machines, or may affirmatively communicate with a designated processor upon occurrence of conditions, such as an alert or alarm condition relating to an operating status parameter of the machine, or on some periodic basis constituting a predetermined period of time. Data relating to rate of change of the inventory may be collected and provided to other processors or the end user. In such applications, it may be particularly advantageous to use wireless communication between the machine and the network. Wireless communication such as from the vending machine to a base station then connected to the Internet may have lower expense and maintenance requirements than a wired connection.

Yet other applications contemplated for use with the systems, apparatus and

methods include personal gas monitoring systems, such as where monitoring may be made for toxic or dangerous substances such as methane. Such systems advantageously include false positive reduction techniques, such as by cross-checking with other sensors.

Applications for remote, distributed sensing include police or military applications. Typically, multiple sensors may be provided in a geographic region, often being dispensed from the air to the ground. Wireless communication then provides information from the distributed sensors to an antenna, whether land based, airborne or satellite based. Optionally, embedded global positioning satellite ("GPS") information identifies the location of the sensors, especially those which are distributed in a manner which does not lead to precise positioning, such as through the airborne distribution of sensors. Such sensors may include motion sensors, such as seismic sensors, particularly adapted to detect the presence of heavy vehicles or armored vehicles.

Yet other applications include process control systems. Pharmaceutical plants or petroleum refining plants require substantial and continuous monitoring and control. Ingredient quality, the presence of contaminants, or other physical parameters may be monitored.

Yet another application includes use of sensor in toys which include a processor (microprocessor). Wireless communication capacity is added which permit sensor data to be passed to the network (Internet, intranet, LAN, etc.) and to be used for monitoring or control, or interactive play between one or more players.

A variety of environmental parameters may be monitored and controlled with such systems. For example, indoor air quality monitoring may be effected, with an actuator serving to modify the conditions, such as to increase venting or to otherwise alert or alarm the occupants of the structure regarding air quality. Water quality may be similarly monitored. Environmental detection of environmental hazards may be remotely distributed. A further example would include embedded detection of Freon degradation in refrigerators, such as through the monitoring of evolved hydrogen, to determine when the refrigerant needs to be replaced.

Security aspects may be included within such systems. For example, a sensor may monitor for the presence of heat and gas, an optical (camera) may be used to detect leaks, monitor for intrusion, etc. Typically, combinations of detected events may lead to more accurate detection and discrimination of events. Optimally, intelligent rejection of false

alarms is effected.

Accordingly, one object of this invention is to provide systems, architectures and methods for the effective use of large numbers of remotely based sensors, clustered sensors, or detectors.

It is yet another object of this invention, systems, methods and architectures are provided for the utilization of the global span of distributed networks, especially the Internet, to utilize sensors coupled to it.

It is yet another object of this invention to provide for the remote monitoring of hundreds or thousands of locations for remote environmental or process monitoring.

It is yet another object of this invention to provide systems which reduce the amount of data required to be transmitted between a remote sensor and an end user to effect successful control.

It is one object of this invention to provide a computer program embodied on a computer readable medium for the controlling, processing and use of sensed data signals relating to environmental parameters.

It is yet another object of this invention to provide systems, architectures and methods which reduce the amount of processing required and end user location.

Brief Description of the Drawings

Fig. 1 shows a cross-sectional drawing of a cantilever capacitive sensor.

Fig. 2 is a block diagram of the interconnection between a digital sensor and an end user processor via net, such as the internet.

Fig. 3 is a block diagram of the distributed self-organizing networks and solutions.

Fig. 4 is a block diagram of system components as may be interconnected via a network, such as the internet.

Fig. 5 is a diagram of one implementation of the layers of software.

Fig. 6 is a block diagram of one architecture for interconnection of a plurality of sensors, nodes (clusters) and an end user.

Fig. 7 is a block diagram of an architecture for interconnection of a plurality of sensors, nodes (clusters) and end user.

Fig. 8 is a block diagram of an architecture for the connection of the plurality of sensor-node groups with a node for sensing a subset of sensors.

Fig. 9 is a flowchart relating to the operation of the sensor system.

Fig. 10 is a flowchart relating to the operation of a node.

Fig. 11 is a diagrammatic view of a wireless camera system. Fig. 12 is a diagrammatic view of a wireless diagnostic chip system for health care related applications.

Detailed Description

In order to more effectively describe the inventions disclosed herein, Applicant provides the following definition of terms:

A "sensor" generally refers to a device for detecting a parameter and providing a signal output.

A "detector", in context, means a sensor plus processing circuitry and/or software to modify, process or analyze the signal outputs of a sensor. A detector may, in certain contexts or applications, be synonymous with a sensor.

"Digital sensor" means an analog or digital sensor assembly having a digital output.

An "analog sensor" means an analog sensor with signal conversion to digital output; or a straight analog sensor connected directly to a microprocessor bus with no digital conversion.

A "biosensor" or "Chemosensor" is an analytical tool or system including immobilized biological or chemical material that produces a signal when exposed to a particular substance, and a transducer which said signal to an easily-measurable electrical signal.

A "node" is a processor which may be connected to a network.

A "sensor-node cluster" is a collection of at least one sensor, preferably multiple sensors, and at least one node.

A "thin server" is a microprocessor system which connects to a network, such as the Internet.

"Statistical data" consists of sensed data which has been in some manner processed, such as through averaging or other statistical processing.

"Array Sensor" is a sensor package that detects more than one parameter on the same chip or package.

Description of the Overall Systems

Fig. 2 is a block diagram showing components of the overall system. The digital sensor 20 has impinging upon it one or more stimuli. As shown in Fig. 2, environmental/process or optical information is shown by the arrows leading to the digital sensor 20. The range of detectable conditions is essentially unbounded, requiring only the existence of a suitable sensor for detection of the stimulus or parameter. The digital sensor 20 is coupled to a communication device 22 by an electrical (or wireless) interconnection 24. The communication device 22 may also be identified as a thin server or interface to a network. The stimuli impinging on the digital sensor 20 may, in certain applications, be provided to a remote processor 26. The remote processor 26 may also be termed the end user. In contemplation of major aspects of these inventions, information is provided from the digital sensor 20 to the processor 26 through an intervening communication system, such as a network 28 and most preferably, the internet (but likewise LAN, Ethernet, WAN, Ultrawideband, or Hyperlan). The network is under control of appropriate network management software and control. Communication from the communication device 22 to the network 28 may be either through a wired connection 30 or wireless connection 32. Likewise, the connection between the processor 26 and the network 28 may be via a wired connection 34 or wireless connection 36.

Fig. 3 shows a block diagram view of a distributed, self-organizing network and possible solutions or applications. Sensors provide the interface or contact to the physical environment. As described in more detail, below, the sensors may be of any type consistent with the parameter to the measured. By way of example; the sensor may detect physical, chemical, physiological, optical, or other parameters. The sensors provide sensor data for a communication system. The communication system, as well as the connection for sensor data and other communication through, from and between the sensors and the communication system may be either wired or wireless, or a combination of both. As seen in Fig. 3, the sensor data is coupled first through a wireless LAN (Local Area Network, Home RF network, etc.). The communication may be of any form or format consistent with the functionalities of this invention. For example, the wireless LAN may utilize radio frequency type communication (RFID at 13.6 MHz or lower frequencies), or a store and forward type systems, or other higher frequency communication systems, such as spread spectrum at 916 MHz or 2.6 GHz. These nodes of

communication are merely representative, and are not meant to be in any manner limitative. The wireless LAN is then coupled to a wireless WAN (Wide Area Network). Again, exemplary technologies for such a system include CDPD, ARDIS, GSM Mobitex, Tetra, Hyperlan, UBCDMA (Ultra Wideband),IS/95, and any additional satellite network.

In one implementation of these inventions, the sensors and the communication network cooperate to provide a distributed, self-organizing network of wireless sensors. The system self organizes through communication between devices or components via the communication system. For example, a sensor or node may communicate through the communications system to sense the presence or activities of other sensors. The action of the network is to control that at least in part locally, as oppose to having been constructed and defined as such in a higher level type of system. The sensors may determine the presence of other sensors, may determine the functionalities of other sensors, and may modify their activities functionalities based on that information.

As shown in Fig. 3, the communication system couples to a data management service. As shown, the communication system couples to a internet data hosting server or other communication portal. The server is coupled to a scalable data base or Object Oriented Database, e.g., Oracle database, Pervasive Software database, Object oriented Database ("Jasmine"), etc. The data in the data base may then be monitored or mined as required. For example, data extraction or data mining techniques may be utilized. Reports may be generated as required by the end user or customer. The existence of one or more conditions may result in the generation of alerts or alarms. An alert comprises a lesser urgent state than an alarm condition, nevertheless requiring consideration and possible action.

In one aspect, the invention relates to a business model or method of doing business and the methods, apparatus and control systems (including software) required to effectuate the business model. The business model or method broadly consists of the steps of receiving data, most preferably real time data being provided via the internet or other global communication network, aggregating the received data, or performing data management services, such as the analysis or mining of the data, and providing an output such as an action to the customer. The service is preferably performed on a subscription fee basis, whereby the business performing the steps of the method receives a fee, typically from the person or entity receiving the output of the system.

Fig. 3 provides examples of various solutions. The solutions may be industry specific. As described in greater detail, below, exemplary applications or solutions include indoor air quality monitoring, utility monitoring and medical monitoring, various consumer point of sale (POS) applications include product quality monitoring, and security, and other applications include industrial process control.

Fig. 4 shows a block diagram of one possible physical arrangement of the system. A network connection 40, preferably an internet connection, serves to couple the sensor assembly 50, the node 70, the actuator assembly 90 and the end user/processor 110. Connections (wired or wireless) 42, 44, 46 and 48 between the network connection 40 and the sensor assembly 50, node 70, actuator assembly 90 and end user/processor 110, respectively, is provided. Exemplary modes of communication through the network, and the signals they represent, include http (hyper text transfer protocol) and shttp (secure hyper text transfer protocol).

The sensor assembly 50 includes at least one sensor 52. In the preferred embodiment, the sensor 52 comprises multiple sensors (or array sensors), e.g., 10 sensors fabricated as microcantilevers on a single chip. The types of sensors useful for these systems will be described in detail, below. Preferably, the sensors are relatively small (so as not to perturb the environment which they are sensing), inexpensive, low/power sensors prepared preferably, the sensors may operate for one or more days without user intervention, having minimal need for calibration, zeroing, reagent topping, cleaning and/or battery changing. In the event that the sensor 52 provides an output which is analog, analog electronics 54 are adapted to receive the analog signal output of the sensor 52. Again, assuming an analog output of a sensor 52, an analog to digital converter 56 receives at its input the output from the analog electronics 54, if present, or from the sensor 52 if no intervening electronic processing is performed. In the event that multiple sensors 52 are included, additional analog electronic circuitry 54 and analog to digital converters 56 may be included. As is known to those skilled in the art, various multiplexing or device sharing techniques may be utilized to reduce the number of components on the device. The digital output from the analog to digital converts 56 may be passed via the connection 42 to the network 40.

The system preferably includes a single chip including both the sensor, required logic components or processing components, e.g., microprocessor, and a wireless

transmission component, e.g., radio frequency generator, all included within a single chip. By integrating the sensing, processing (optional memory), and transmission functionalities, the device may be made compact and robust.

The sensor assembly 50 may optionally include a processor 60, typically disposed between the output of the analog to digital converter 56 and the network connection 58. The processor 60 may be an embedded processor. While it may be formed as a conventional microprocessor, with all of its attendant functionality, it may also be a processor more particularly adapted to the tasks required of the sensor assembly and the communication and processing of sensed data. One such processor may be an ARM processor. Such a system is a RISC (reduced instructions set computer). Such systems are available as a processor core, provided as intellectual property for inclusion in a chip design. Additional processors may include a stand alone PC (such as desktop chassis by INTEL; single board PC (Intel); industrial single board computer (Intel, Motorola, etc.); Microcontroller with chips; or Custom processor on a single chip). All these designs are capable of network connections as well as signal processing.

Various programming methodologies may be utilized, as well as novel real-time operating systems (RTOS) for data management Advantageous code exists, and continues to be developed, which permits processing of data and is particularly adapted for Internet connection and communication. One such system is known as Jini (or JAVA). Jini is developed by Sun Microsystems. One advantage of such systems is that it permits a device, such as the sensor assembly 50 with its own RTOS, to be plugged into the net 40, and Jini devices are enabled to communicate with yet other Jini devices. When Jini devices are added to the net, such as the Internet, the devices may register with yet other devices, to provide identification information and functionality descriptions. Auxiliary devices may include either external to the processor 60 or internal to it. For example, memory such as RAM 62, ROM 64 and mass storage 66 may be included as desired or necessary. Memory may be utilized to store sensed data as provided from the sensors RTOS 52, and may also be utilized to store program information which achieves the functionality described herein.

The node 70 includes a processor 72. The processor 72 may be of any type consistent with the functionalities required, though the structures and functionalities described in connection with the processor 60 of sensor assembly 50 may be utilized for

the node 70. A network connection 80 serves to interconnect node 70 to the net 40 via connector 44. The node 70 serves to perform various functions, many of which will be described throughout the specification, though possible functions include: processing of data received from one or more sensor assemblies 50, performing data analysis on information received from the sensor assembly 50 or user 110 to provide control or information to the actuator 90, to communicate with the end user 110, to provide redundancy to the system and to provide the possibility of direct access via a web browser over the Internet to access the node 70, and to thereby obtain information or control over or from the sensor assembly 50 or actuator assembly 90.

The processor 110 associated with the end user is coupled to the net 40 by connection 48. A network connection 112 provides for communication between the processor 114, running application software 116 and the devices described previously over the net 40.

The systems, methods and architectures of these inventions may be utilized with a wide variety of sensors, and software designed for these sensors. Various types of sensors contemplated include mechanical sensors, especially microcantilever sensors, micromachined sensors or microbalanced mechanical sensors. Any forms of MEMS based and sensor-actuator combination consistent with the functionality of the invention may be utilized. Other types of sensors include: biosensors, electric field sensors, magnetic field sensors (microbalance, microcantilever, magnetoresistive, and SQUID sensors), optical sensors (e.g., photo responsive electrodes, CCD arrays, digital or analog cameras), micromirror arrays, optical switches, optical and electrical routers, , chemical sensors (e.g., chemFET, MOSFET, electrochemical, metal-oxide semiconductor film, chemiresistor, and surface acoustic wave sensors), spectrometric sensors (e.g., UV, visible or spectrasensors, surface enhanced RAMAN scattering sensors, gas chromatograph/mass spectrometry), thermal sensors (e.g., thermoresistors, thermistors, thermocouples, thermopiles, calorimetric cantilevers, sensing for temperature, thermal conductivity and/or heat capacity), , etc.. Optionally, multiple sensors may be included within a single sensor assembly, for example, a multiple-cantilever chip, having e.g., 10 or more sensors, may be utilized (array sensor). The output of the various sensors may then be combined for analysis and identification of the environmental condition. The items sensed may include chemicals (e.g., CO, O_2, NO, Argon, Redon, Lead (Pb), small molecules (gas or liquid

state), NH_3, CO_2, H_2S, CO_2, H_2S, CO_2, H, toxic gases, etc.), explosives (e.g., TNT), metals (e.g., mercury), organics (e.g., volatile organics, propane, methane, NOX.), humidity (e.g., water vapor). Biological materials may be sensed (e.g., DNA, RNA, antibodies, antigens, proteins, bacteria, viruses, enzymes, spores, antigens, bacteria, anthrax, cells, blood, etc.). Electromagnetic radiation can be sensed (e.g., light, infrared, microwave). Physical parameters may be sensed (e.g., pressure, flow, temperature, turbidity, viscosity, and acceleration (linear and/or angular), voltage, power, current, bits, etc.). The form of detected material may be any suitable for detection, whether gas, liquid or solid (such as particulate matter). In one aspect of this invention, multiple sensors may be included within a given sensor assembly. Some or all sensors may be redundant sensors. Alternatively, various sensors may sense different parameters or conditions, such as temperature and gas, or aromatics and temperature. The sensors may cross respond to multiple inputs. For example, a hydrogen sensor may cross-respond to humidity and temperature, the use of humidity and temperature sensors within the system of by permitting correction of those effects.

The various sensors 52, 100 and actuators 92 may be implemented through various microelectromechanical devices, also known as MEMS. While various of the sensors described previously may be broadly classified as MEMS, not all would be so classified, and the category of MEMS may include devices not previously listed. Further, it will be appreciated that the identification of components as being located within one device, such as the sensor assembly 50, or within another device such as the actuator assembly 90, may be provided in other locations or in conjunction with those other devices.

Yet other structures may be advantageously utilized in conjunction with the previously described systems. For example, containment vessels or fluidic delivery systems may be utilized in conjunction with the sensor assembly 50 and/or actuator 90. The vessel may contain materials such as a fluid, gas, organism or solid biological or chemical samples. Further, the sensors 52, 100 may comprise multiple sensors. The multiple sensors may be to some degree redundant sensors, to ensure robust and long lasting operation of the system, so as to avoid down time or other disablement, or may serve as an error checking or double checking system to avoid the occurrence of false positive signals. Further, multiple sensors may be adapted to sense different stimuli, or to respond to a given stimuli in different ways. The output from the sensors may be utilized

either alone or in combination with other outputs or other information to provide for more accurate detection. For example, various 'electronic noses' sense various materials or aspects of those materials, and utilize the collective response information in an effort to identify a given substance or substances. In yet further implementations, when multiple sensors are utilized, the sensors may be adapted for detection of different types of materials, such as certain sensors being for gas sensors, others for liquid, and yet others for solid materials, such as particulate matter.

The analog electronics may include various read out functions. For example, signal processing may be performed on the analog output of the sensors 52. (Comments made with respect to sensors 52 may be considered throughout to be equally applicable to the sensor 100). The analog electronics may further include various circuitry such as lock-in circuitry, which detects the amplitude and/or phase of an oscillating signal at a given frequency. As many forms of sensors include resonant structures, such as microcantilevers, circuitry which serves to accurately identify the frequency or spectral response of the sensor may be advantageously employed.

The analog to digital converter 56, 94 and analog to digital converter 102 serve to convert signals from analog to digital, and vice versa. Many forms of such circuits are known to those skilled in the art. The degree of precision or required may be determined in reference to the sensor and the desired functionalities be achieved from the system and methods. While many sensors are by their structure and operation analog devices, certain sensors have aspects which are 'digital' in their structure or mode of operation. For example, a simple switch actuated by the presence of a force field, such as a magnetic force, electrical force, flow, vibration or temperature change, which causes the closing or opening of a switch with a sufficient stimulus, has certain aspects of a digital device. Photo-optical switches or chemically activated switches may, in certain implementations, also bear certain digital aspects. Accordingly, the components such as the analog to digital converters 56, 102 and digital to analog converter 94 will be determined in their structure and functionality to meet the overall functionalities required of the system, as described herein.

Various communication protocols may be utilized to implement the systems, architecture and methods of these inventions. While not meant to be exhaustive, representative application-level communication protocols include: http, https, FTP (file

transfer protocol), and SMTP (simple mail transfer protocol). While the preferred network 40 is the Internet, the system may also include as part or all of this communications network other forms of networking consistent with achieving those functionalities. Like the Internet, such other networks may consist in part of, public digital telephone circuits accessed by telephone or television cable (CATV) modem, by digital subscriber loop technology (DSL), or by a router connection. Various other wide area networks (WANs) or local area networks (LANs) may be utilized.

To restate to some degree, sensors 50 are connected to the network 40 by a microprocessor and a network interface 58 in conjunction with a communications protocol suite. The network may be a local area network (LAN, such as Ethernet), a metropolitan area network (MAN), a wide area network (WAN), or an internet (such as the Internet).

Network interface 42, 44, 46, 48 to LANs may be wireless or wired. Wireless LANs can be commercially-available IEEE 802.11 systems or proprietary systems designed for a specific application. Wired LANs include AppleTalk, the Foundation Fieldbus and the Dallas Semiconductor one-wire bus, but are exemplified by the Ethernet standard. An Ethernet connection can be effected with an network interface chip or chipset; optimally, the microprocessor and network interface chip are combined on a single chip ("network capable application processor") such as NETsilicon's NET+ARM processor. The Ethernet connection may be provided as part of a product such as a "thin server", or a palmtop, laptop, or personal computer equipped with a network interface card.

Internets, including the Internet, and WANs may also be accessed by wireless or wired connections. Sensors may be connected to wireless WANs via proprietary wide area packet data networks such as Motorola DataTAC (ARDIS) or Mobitex (RAM), or by standardized telephone-based systems such as Cellular Digital Packet Data (CDPD), Personal Communications System (PCS), circuit-switched cellular, or satellite services (i.e., Iridium). Wired connections may be provided by a telephone or cable television (CATV) modem, by a digital subscriber line (DSL), or by router connection of a LAN to a digital telephone circuit.

Protocol suites for communication with the end user are exemplified by the TCP/IP suite. Communication between nodes and sensor assemblies may use simpler protocols to

reduce the complexity and cost of the sensor assemblies, especially when the node and sensor assemblies are located within a single building.

Fig. 5 shows one possible implementation of the software levels. At the lowest level, a hardware interface is provided. This level provides subroutines that access the various hardware components, such as sensors,. Ann operating system (potentially a real-time operating system or RTOS) with graphics, I/O, and networking libraries provides the next layer. Optionally, the next layer comprises a JAVA virtual machine. Finally, application programs, whether standard or custom may be provided.

Fig. 6 shows an architecture for implementation of the system and methods described herein. This architecture is particularly advantageous for large numbers of sensors, such as those systems having 100 or more sensors in them. Fig. 4, Fig. 5 and Fig. 6 are intended to depict conceptual arrangements of components, as compared to Fig. 3 which shows a physical layout of components in one implementation. Fig. 4 shows a plurality of sensors 120 connected to a node 122. The interconnection between sensors 120 and node 122 consists of connections as described in Fig. 3, such as the network, such as the Internet or other communication path. The path may be either wired or wireless. The node 122 is yet further connected to the end user 124. The interconnection between the node 122 and the user 124 may be as described previously, and again, either wired or wireless in whole or in part. As shown, an optional actuator 126 may be operatively connected to the node 122. Fig. 7 shows a conceptual arrangement in block diagram format of a higher lever hierarchy of sensors and nodes. The sensors 130 are coupled to the node 132. This collection may be referred to as a sensor-node cluster. There are multiple sensors 130 connected to at least one node 132. This first sensor-node cluster 134 is then coupled to the processor/end user 136. The second sensor-node cluster 134", and third sensor-node cluster 134'" are coupled to the processor-end user 136.

Fig. 8 shows an architecture having a first sensor-node cluster 144 which includes a plurality of sensors 140 and a node 142. A second sensor-node cluster 144" includes a plurality of sensors 140" and a node 142". A third node 146 is coupled to one of the sensors 140 of the first sensor-node cluster 144 and one of the sensors 140" of the second sensor-node cluster 144". The third node 146 may be coupled to different number of sensors 140 in the first sensor-node cluster 144 then to the number of sensors 140" in the second sensor-node cluster 144". The third node 146 may be connected to all sensors 140,

140". However, in the preferred mode, the third node 146 will be coupled to some, but not all, of the sensors 140 in the first sensor-node cluster 144, and likewise, some, but not all, sensors 140" in the second sensor-node cluster 144". The nodes 142, 142" and 146 are coupled to the processor-end user 148. x

The operation of the architecture of Fig. 8 may be understood more clearly by way of the following example. This example is provided for purposes of illustration, and not for limitation. For example, the first sensor-node cluster 144 and second sensor-node cluster 144" serve to provide information regarding all sensors at a given location via the nodes 142, 142". The third node 146, as drawn, is coupled to less than all of the sensors in the first and second sensor-node clusters 144, 144". The third node 146 might, for example, be connected to all temperature sensors, designated in Fig. 6 as the center sensor 140, 140". In this way, processing of specific information may be facilitated.

The methods of communication between the various devices may be initiated by any device or done on a polling basis. For example, polling of locations may be performed on a periodic basis, or based upon some other criteria, such as the expected time or date for occurrence of an event. In yet another example, a node may accumulate data through communication with various sensor assemblies, and then provide periodic data to an end user. The data may comprise the raw data or, processed data, statistically analyzed data, or merely results based upon the underlying data.

Optionally, neural networks may be utilized in conjunction with the systems and methods described herein. Such neural networks for fuzzy logic systems typically receive multiple signal inputs and processes or analyzes those signals so as to generate an output useful as an indicator of a pattern or substance recognition. For example, taking the case of gas detection, a multiple sensor chip, such as a 10 sensor (e.g., microcantilever) chip may provide 10 outputs which are provided to a neural network/fuzzy logic system. The supplied input signals to the neural network are cooperatively analyzed to aid in determining an output. The intensity, frequency, amplitude, phase, rate of onset or other parameters may be utilized in this analysis. As yet another aspect of the invention, the neural network or fuzzy logic may be arranged in a distribured manner. For example, a neural network may have components which are located at multiple sensor assemblies, yet backed in a cooperative manner, or are distributed between various nodes, or are distributed between combinations of sensor assemblies and nodes. In such a distributed

manner, components of the neural network would communicate or cooperate over the network, such as the Internet.

In one aspect of this invention, the system includes a fault tolerant distributed memory. This fault tolerant distributed memory is applied to self-organizing networks of the distributed sensors described below. Since there is a risk of loss of one or more sensors in the system, whether due to device failure or other mode of destruction or damage to the sensor, it is desirable to include a system which has redundancy of the stored data. Assume that the system includes N Sensors, each storing M measurements of a target parameter. By way of example, if there are 100 sensors and 100 measurements of the target parameter, that there would be 10,000 data points. Assuming 100 bytes per sample, a total data storage of 1 megabyte would be required for the 100 sensors.

One possible fault tolerant solution is to include enough memory in each sensor to store the entire data set generated by all sensors. This solution tends to be the highest cost solution, and results in quadratic complexity in sensor memory (as the complexity increases as M).

One alternative is for each sensor to store its own data set plus one point from each of the other sensors data sets. One example is provided:

S_k stores:	$S_k(t_1)$ $S_k(t_2)$ $S_k(t_m)$	M points
+	$S_1(t_{k1})$ $S_2(t_{k2}$ $S_N(t_{kN})$	N points

While this solution increases the memory as a linear function of the number of sensors N. Thus, the approach is practical for large networks.

Assuming that Node S_i is lost, the other nodes are interrogated and the S_i data set may be reconstructed as follows:

From	S_1	$S_i(t_{1i})$	$\{t_{1i}, t_{2i}, \ldots t_{mi}\}$
	S_2	$S_i(t_{2i})$	permutations of
	S_N	$S_i(t_{N1})$	$\{t_1, t_2 \ldots . 1tN\}$

After sorting, the assigned data is restored. If more than one node is lost, the data set from any of the lost nodes can be reconstructed to an approximation by retrieving all remaining data points from still active nodes and interpolating to estimate the lost points.

As yet another level of improvement in fault tolerance, more copies of each data point may be written onto the network. In that way, more sensors or nodes may be lost, yet with the ability stored to reconstruct all of the data, either completely or to the best

approximation. While adding more memory increases that usage over to N, the addition is still linear (as opposed to a higher power such as quadratic).

Conversely, if a lower degree of fault-tolerance is required, memory and network bandwidth can be conserved by storing forward error correction (FEC) codes, such as Reed-Solomon codes, rather than copies of data points. For example, if the network only needs to tolerate the loss of 10% of its sensors, it only needs to store one error correction codeword for every ten sensors. This would be a 10% redundancy Reed-Solomon code. The FEC code redundancy that is actually used will vary depending on the application.

Fig. 9 is a flowchart relating to the operation of the sensor assembly system. After the start block 150, when a device is installed at step 152 to the net, and initialization procedure may optionally be effected. One option is for the device to register with the local node 154. Registration may identify the device as to address or other identification number, and optionally, as to the intended function of the device. After installation and registration, the sensor assembly is placed in a data acquisition and/or analysis node. In the embodiment described herein, the receipt of an external stimuli at the sensor assembly results in generation of signals as output from an analog to digital converter 56 (See, e.g., Fig. 3) whereupon the data may be stored in writeable memory 62, 66 or other memory within the processor 60. After a periodic wait step 158, which may vary in duration from, for example, 0.1 to 600 seconds, the sensor assembly 60 checks for instructions sent from the node at step 160. If no instruction has been sent from the node at step 160, the sensor assembly 60 may continue to move to step 156 as to record further digital values output from the analog to digital converter and stored in memory. In the event that an instruction is sent from the node at step 160, a variety of actions may be taken. The selection between actions may be based upon decisions by the processor 60, or based upon instructions received from the node 70 or other device, such as the end user/processor 110. As shown in Fig. 7, various options are available. This list is not exhaustive, but rather merely representative. For example, one option upon either receiving an instruction from the node at step 160, or upon occurrence of a time out, the processor 60 may calculate a value and send data from the last reporting time in step 162. As an alternative, the sensor assembly may send all values stored at step 164. As yet another alternative, the sensor assembly may send a particular value at step 166, whether a previously stored value or a value obtained in real time.

Fig. 10 is an exemplary flowchart of operation of a node (See, e.g., node 70 in Fig. 3). At the start block 170, process flows to an installation step 172. As described in connection with the sensor assembly 60, the device at an installation step 172 may perform initiation as to locate the presence of other devices, such as sensor assemblies 60 or actuators 90. Installation 172 may consist of obtaining the identity of other devices and an indication of their function. Additionally, the node 70 may register with the central database at step 174. The central database may reside at the end user/processor location and comprise the computer 114. After the initiation step 172 and registration step 174, the node 70 may then perform any of the various activities described herein. Fig. 8 provides merely representative examples of possible steps. Continuing with the selections made in Fig. 7, the node 70 may at step 176 act to obtain data from the various sensor assemblies 60 which have been accumulated since the last update. After the data is obtained, a time out procedure is begun at step 178. Receipt of an instruction from the user or other device at step 180 may lead to an action step 182. Alternatively, if no instruction is received at step 180, the system continues to loop and wait for expiration of the time until the next data acquisition step or until receipt of an instruction from the user or either source.

Fig. 11 shows a diagrammatic view of a video camera system as one mode of sensor or input to the systems of this invention. A video camera 190 is coupled to a transmitter 192 having a wireless connection 194 to a receiver 196. The transmitter 192 and receiver 196 are each equipped with antenna 198. The receiver 196 is optionally couples to a video monitor 200 as well to a video server 202. The video server 202 or other storage device is then coupled through a further communication path to the remainder of the system such as by an internet connection, DSL connection, or dial out modem or any other form of communication consistent with the capacity and the requirements.

Optical switches may be formed utilizing all those of MEMS (MicroElectroMechanical System) devices. The cantilever (see, e.g., cantilever 12 in Fig. 1) may be coated with a reflective material such as gold, thereby forming an optical mirror. Optical networking may be effected by routing using the actuator properties of the cantilevers. The cantilevers serve to convert the user bits automatically via the actuator properties of the device. The systems, architectures and methods disclosed herein may be used in an extremely wide variety of applications. The applications described below are

merely exemplary. Further, the various functional aspects described with respect to one application may be utilized in yet other applications.

Remote Food Sensing Applications

Purveyors of food products face a number of challenges in the retail distribution context. For example, uneven food quality is an undesirable aspect of retail food sales, with this problem being especially acute for geographically diverse companies. By way of example, a soft drink manufacturer and distributor such as Coca Cola, has essentially global distribution of soft drinks. The more local action which is required regarding the preparation and service of a drink leads to an increased likelihood of uneven quality. For example, sales of drinks from a fountain which requires mixing of local water with a regionally prepared syrup or base mixture may have dramatically different qualities or taste profilers or attributes around the globe. Brand name recognition leads to an expectation of quality and particular taste, and heretofore, the sensing of quality and the ability to control the quality has been clearly less than optimal. In yet another aspect, such food sellers wish to minimize erroneous delivery of product. For example, they wish to minimize or eliminate the erroneous delivery of a drink as being a diet drink when in fact, it is a regular drink. Similarly, the delivery of a caffeinated product when a decaffeinated product is desired may lead to serious health or allergic reaction consequences to the consumer.

In implementation of a large scale monitoring system, such as a global monitoring system, a variety of sensors may be utilized. Sensors monitor the quality of the ingredients. By way of example, the water quality may be monitored for any number of a variety of parameters, including the ion content, metal contents, viscosity, density, temperature and aromatic profile. The quality of other ingredients, such as the amount of carbonation in a fluid supply, or quality of raw ingredients such as sugar. In addition to sensing for the quality of ingredients, sensors may be provided for protection of contaminants. For example, sensing may be performed for biological contaminants such as bacteria, viruses, or otherwise. Various biosensors are available to detect biological contaminants. See, e.g., (No.. 5,372,930; No. 5,807,758, application No. 08/794,979; app. No. 09/008,782, app. No. 09/074,541 , incorporated herein by reference as if fully set forth herein.

Yet other sensors may be provided to detect physical parameters. Exemplary

parameters may include pressure (either gas or fluid), temperature, viscosity, density, or flow rate.

In operation, the sensors may monitor for the various parameters required as input, such as those described previously. Certain of the parameters require physical contact with the materials, whereas other parameters or stimuli may be sensed without contact, such as through the use of an 'electronic nose' to detect volatile compounds. Generally, it is desirable to avoid contact with food products, and thus a non-contact sensing is preferred. In addition to sensing ingredients interim mixtures, the final product may also be sensed.

Sensing of the various parameters may be done continuously or periodically, and also in an instantaneous (one-time) fashion. Sensing may be performed merely for the purposes of generating a record or information, or may be used to effect action. For example, the sensing of ingredients detects a situation requiring action to ensure that the final products conforms to the specifications, then a feedback or closed loop action may be taken so as to change aspects of the ingredients or the recipe or method of treatment of those ingredients in the process. Such control may be effected at a purely local level, such as through the action of the processor 60 itself, or through processing at the node 70, or yet at the processor/end user 110. The actuator assembly 90 (Fig. 3) shows the combination of a sensor 100 and actuator 92 which may be advantageously utilized for the dual purpose of sensing and taking action based upon the sensed data. In yet other implementations, various sensor assemblies 60 or nodes 70 may cooperate in a regional manner. For example, if a contaminant is detected by one sensor assembly 60, other sensors associated with a node 70 within a given sensor/node cluster may be notified. In yet another aspect, when a contaminant or other process parameter is detected to be out of specification, an alert or alarm condition may be generated. Such alerts or alarms may be provided locally, as well as reported to the end user.

Structurally, multiple sensors may be formed on a single support, substrate or chip. Multiple flows of materials may be monitored through multiple sensors.

Vending Machine Status Example

Yet another example from the food distribution context is found in the monitoring of vending machines. Typically, the product distributed through a vending machine is wholly fabricated and packaged. The parameters which may be sensed in this context

relate more to the operating status of the machine, such as power consumption, temperature, inventory, or the presence of money for change. By monitoring sales information and time of sales, the rate of sales of various items may be collected. That information may then be utilized in deciding when restocking is required, and in deciding what items to restock and in what quantity.

The use of wireless communication is particularly advantageous in a vending machine context. Oftentimes, vending machines are placed in locations which are conveniently located to a power outlet, but otherwise not conveniently located to a wired telephone or network connection. The use of wireless communication for at least part of the communication path to the system would permit placement of vending machines from a sales standpoint.

Personal Gas Monitor Example

In yet another application, sensors may be utilized for detecting local conditions which may affect a relatively small number of persons. Personal monitoring may be done extremely locally, such as where a personal monitor is worn by one individual or may be disposed within a region, such as within a conference room, class room or other localized space. By way of example, materials for monitoring could include: formaldehyde, CO_2, H2S, CO, organics, methane, toxins, and biological or chemical entities. While useful in other context, such systems advantageously benefit from cross-checking between sensors, so as to reduce false positives. A sewer, petroleum processing industry, or mining worker with a personal gas monitor which monitors for methane or other volatile organic gases may benefit from a system, though desirably that system would minimize the occurrence of false positives. Actuators may be utilized based upon processed data such as where vents are controlled based upon detected gas or contaminant conditions. The gas to be detected may be hazardous or non-hazardous.

Military and Police Example

Numerous applications in the military or police arenas exist. In one implementation, numerous individual sensor assemblies may be distributed over a geographic region, such as an area of conflict or a relatively high crime area. These sensors may be precisely positioned, or may be distributed in a manner which leads to some randomness in their physical positioning, such as by dropping sensors from an airplane. Typically, the sensor assembly would communicate with the remainder of the

system through a wireless connection. The communication may be with a ground based antenna system, with and airborne detection system or with a satellite system. Preferably, the sensor assemblies would include position detection equipment, such as a global positioning satellite (GPS) system. The positional information would then be transmitted to the node 70 or end user 110 for use with other processing of the data. In such applications a sensor for motion, such as seismic activity, may be utilized to indicate the presence of a heavy vehicle or armored unit.

Process Control Example

Numerous examples may be provided relating to process control such as at a pharmaceutical plant, smoke stack emissions, or at a petroleum refinery. Yields may be increased by directly monitoring parameters such as ingredient quality, presence of contaminants, presence of toxic gases or liquids, physical parameters or the presence of error conditions.

Explosives Detection Example

Numerous sensors exist for the detection of explosive materials. Detectors indicated in critical areas may communicate through wireless communication with a local node or an end user processor. For example, baggage handling areas of airports may include explosives monitors; conversely, distributed detectors may be used for mines on the battlefield.

Environmental Detection Example

Sensing of materials relating to environmental quality may be performed in a variety of ways. For example, embedded detectors located within refrigeration or air conditioning units may monitor for degradation of Freon or other materials known to have deleterious effects on the environment. Freon degradation may be detected by monitoring for hydrogen. Numerous hydrogen sensors exist. By including such sensors in appliances as originally manufactured and delivered to customers, the environmentally effective operation of devices may be monitored, and corrective action be taken upon detection of a suboptimal condition. Wireless communication from at least the sensor assembly to at least the remainder of the system facilitate the effective monitoring of appliances.

Business, Consumer, and Home Security Examples

Numerous applications of sensor systems and methods may be adapted for business or home security use. For example, the sensors may monitor for

heat/temperature, gas, toxins medical health data (Temperature) or environmental hazards. A combination of detected events may lead to more accurate detection and discrimination of events. By analyzing conditions against known existing patterns, a more accurate security system is provided; even inventory control can be accomplished by wireless means.. Intelligent rejection of false alarms may be effected by comparing against regular patterns, or by suggesting further sensing to be performed prior to issuing an alarm condition. In addition, individual appliances such as microwave ovens, washers, refrigerators, standard ovens, stoves, blowers, etc. in the home may have single or multiple embedded sensors for measuring multiple parameters such as toxic gases, etc. These again would be coupled to a thin server system and ultimately to the home intranet, Internet, WAN or LAN for data management.

Portable Appliances, Containers, Vessels, and Detectors Examples

Numerous applications for sensor systems may be adapted through portable devices, such as DNA/RNA or bio-detectors; cargo containers, boxes, beakers, paint cans, portable health monitors, glass or plastic vessels or microtitre plates containing, fluids, bacteria, blood, urine, etc. in close proximity to an embedded sensor; which measure certain environmental parameters from a sample. The sample can be gaseous, liquid (such as blood or urine), or solid (such as meat). A portion of the sample is placed close to the detector or sensor which can measure certain parameters such as DNA, RNA, bacteria content, toxin, genetic code, insulin, other hormones, chemicals, Na, K, Biocarbonate, Urease, cardiac enzymes, renal proteins, any chemical or biological indication of disease or bodily function, pressures, flow, temperature, etc. This detector, or vessels or container (or ultimately the single sensorchip on a container) device also contains an embedded server and data management system similar to previously described systems where the data can be transmitted to an Internet, intranet, LAN, WAN, or other network via wireless or wired communications.

Trap Monitoring

Traps such as for animals (e.g., mouse, lobster, bear, beaver) may be prepared with sensors. The sensors may provide data regarding the status of the trap, such whether as the trap has been sprung, whether an animal has been captured, how many animals have been captured, etc. The sensors then may be connected preferably in a wireless mode to receivers which provide the data to the end user regarding the status of the traps. Given the

low frequency with which traps are sprung and animals caught, the remote monitoring permits great increases in cost effective use of traps. Rather than requiring the periodic human review of the traps for an event, the traps may be monitored and only serviced when required.

Toy Applications

Toys may be provided with electronic control systems, such as microprocessor based control systems, to provide for a more interactive or real life like experience for the user of the toy. The toy may further include various sensors, such as could be provided by the use of cantilever/MEMs based infrared detectors as 'eyes' for robotic toys. Other types of sensors may include pressure, temperature or other positional or proximity sensor which may serve to identify the presence or absence of a person or other unit, or to provide yet further specific information regarding the environment around the toy. The sensed parameters result in generation of data, which may be processed by the microprocessor within the toy, or may be processed external to the toy. Preferably, a wireless network interface is provided, though a wired connection would also be usable in certain circumstances. The signals relating to the sensed parameters may then be passed over the network (e.g., LAN, Internet, home intranet) to a processor or remote user. The system may be utilized to permit a single child or user to interact with the toy. Multiple players may interact with a given toy or multiple players may interact with multiple toys, such as where games are placed against various players or in teams. Various players may be remotely located, indeed globally located.

Engine or Rocket/Airplane Engine Monitoring

Sensors can be distributed throughout a rocket, car, locomotive, missile, airplane, etc. engine, collecting data on certain parameters such as gas emissions, fuel control, temperature, pressure, flow, etc. The data would be transmitted by a nodal architecture to a microprocessor and eventually to a display via WAN, LAN, intranet, Internet, RTOS software, JAVA/Jina, or other "plug and play" data management systems would be used. Preferably, data is transmitted in as close to real-time format as possible.

The systems described herein may be implemented in a wide variety of technologies, including both wire and wireless, analog and digital, in various process technologies (e.g., CMOS, NMOS, bi-polar, gallium arsenide). Further, devices may be discrete devices or may constitute integrated devices. For example, sensors may be

fabricated as individual units or multiple sensors may be fabricated on a single support or substrate.

Medical Applications

Fig. 12 shows a medical monitoring application. A patient has implanted within it a device to 212, such as a pacemaker, drug delivery device or other implanatble, electrically controlled device; or a non-implantable health monitor (temperature, blood pressure, respiratory rate, etc.). The device 212 includes sensors for the desired parameters to be measured as well as a short-range wireless data transmission capability. In the preferred embodiment, a "smart bandaid" 214 may affixed to the patient 210. The smart bandaid 214 serves as a receiver for the transmissions from the implanted device 212. The bandaid 214 includes a transmitter, preferably a wireless transmitter, to communicate data a master control unit 216 via a wireless 218. The master control unit 216 is then coupled via a global information network, such as the internet 218 to the end user. For example, the data may be communicated via the internet 218 to a physician, such as through a wireless, portable device 220, such as a palm pilot, or to a wired device 222 such as a computer. Optionally, a data processing step may be included (see, Fig. 3 and the accompanying discussion regarding data management).

The implantable device 212 includes within it a power source. Communication from the implant 212 to the external receiver transmitter 214 can be done in the lowest power mode as possible. For example, the implantable device 212 typically utilized microwatts of power to transmit data to the external/transmitter 214. The external receiver/transmitter 214 may then store and forward or return the missed data over a higher power wireless 218 to the master control unit 216. In this way, the implanted device 212 may conserve its limited battery power, yet still transmit the data over much longer distances when would be possible with direct transmission from the implantable device 212. This system of an implantable device 212, a first receiver transmitter 214 disposed adjacent to patient 210, and a second receiving unit 216 permits the architecture of our distributed data logging and processing between the implantable 212 and the device 214. In yet another aspect, the smart bandaid 213 may be used as a drug delivery device. In a preferred embodiment, the drug delivery device would respond to data provided from the sensors within the implanted device 212.

Metabolic Weight Sensor

Yet another amplication includes the use of sensors such as carbon dioxide or acetone sensors, for use in monitoring metabolic weight. Preferably, the carbon dioxide or acetone is measured by breath analysis via a sensor. A wireless component then communicates the data relating to carbon dioxide levels for analysis of the metabolic weight. One application of such monitoring would be for monitoring metabolic weight as would relate to weight reduction.

Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity and understanding, it will be readily apparent to those of ordinary skill in the art in light of the teachings of this invention that certain changes and modifications may be made thereto without departing from the spirit or scope of the appended claims. Many other examples not stated, where sensor data is collected locally and transmitted to another site, can be implemented using this invention.

We claim:

1. A distributed system for the remote sensing of environmental parameters at a first location separated from a second location by a communications network, comprising:

at least one digital sensor, the digital sensor sensing at least one environmental parameter at the first location and outputting digital information indicative of that parameter,

a coupling for interconnection of the digital sensor to the communication network,

a communications network under control of a network management system, and

a processor coupled to the communication network at the second location, for receiving digital information from the digital sensor passed through the communications network.

2. The system for the remote sensing of environmental parameters of claim 1 wherein the digital sensor comprises:.

an analog sensor generating a signal indicative of the environmental parameter, and

an analog to digital converter receiving the output of the analog sensor and providing a digital output representative of the signal.

3. The system for the remote sensing of environmental parameters of claim 1 wherein the digital sensor further includes readout electronics coupled to the analog sensor.

4. The system for the remote sensing of environmental parameters of claim 2 wherein the analog sensor is a cantilever chip sensor.

5. The system for the remote sensing of environmental parameters of claim 2 wherein the analog sensor is an electric field sensor.

6. The system for the remote sensing of environmental parameters of claim 2 wherein the analog sensor is a magnetic sensor.

7. The system for the remote sensing of environmental parameters of claim 2 wherein the analog sensor is an optical sensor.

8. The system for the remote sensing of environmental parameters of claim 2 wherein the analog sensor is an acoustic wave sensor.

9. The system for the remote sensing of environmental parameters of claim 2 wherein the analog sensor is a chemical sensor.

10. The system for the remote sensing of environmental parameters of claim 2 wherein the analog sensor is a spectrometric sensor.

11. The system for the remote sensing of environmental parameters of claim 2 wherein the analog sensor is a thermal sensor.

12. The system for the remote sensing of environmental parameters of claim 2 wherein the analog sensor is a biosensor.

13. The system for the remote sensing of environmental parameters of claim 2 wherein the analog sensor is a chemosensor.

14. The system for the remote sensing of environmental parameters of claim 1 wherein the detector is a portable unit.

15. The system for the remote sensing of environmental parameters of claim 1 wherein the detector is in the form of a container or cargo in a container, trunk plane, etc.

16. The system for the remote sensing of environmental parameters of claim 15 wherein the container is a vessel containing one or more of a fluid, gas, organism, or solid biological or chemical sample; or contains a direct product such as clothes, appliances, hardware, food, etc.

17. The system for the remote sensing of environmental parameters of claim 15 wherein the container is a cargo container; or monitoring the inventory of cargo carried in a container such as hardware, clothes, appliances, etc. (as typically by a camera).

18. The system for the remote sensing of environmental parameters of claim 1 wherein the sensed environmental parameter is a hazardous or non-hazardous gas.

19. The system for the remote sensing of environmental parameters of claim 18 wherein the gas is CO, Oxygen, volatile organic compounds, non-volatile organic compounds, H2S, 03, NH3, SO2, Oxides of Nitrogen, CL2, CH4, C3H8, HCHO, Sarin, nerve gases, mustard gas, benzene, Pentane, hexane, emissions gases, etc.

20. The system for the remote sensing of environmental parameters of claim 18 wherein the gas is selected from the group consisting of: hydrogen, Freon, and CFCs.

21. The system for the remote sensing of environmental parameters of claim 18 wherein the gas is CO_2.

22 The system for the remote sensing of environmental parameters of claim 1 wherein the sensed environmental parameter is a liquid or dissolved gases in liquid such as CO2, CL, O2, O3, Fl

23. The system for the remote sensing of environmental parameters of claim 1 wherein the sensed environmental parameter is solid.

24. The system for the remote sensing of environmental parameters of claim 1 wherein the sensed environmental parameter is chemical.

25. The system for the remote sensing of environmental parameters of claim 1 wherein the sensed environmental parameter is biological material such as DNA, RNA, Bacteria, Viruses, spores, antibodies, antigen, cells, or blood.

26. The system for the remote sensing of environmental parameters of claim 1 wherein the sensed environmental parameter is a physical parameter.

27. The system for the remote sensing of environmental parameters of claim 26 wherein the physical parameter is pressure.

28. The system for the remote sensing of environmental parameters of claim 26 wherein the physical parameter is flow.

29. The system for the remote sensing of environmental parameters of claim 26 wherein the physical parameter is viscosity.

30. The system for the remote sensing of environmental parameters of claim 26 wherein the physical parameter is density, conductivity, velocity, turbitity, salinity or pH.

31. The system for the remote sensing of environmental parameters of claim 26 wherein the physical parameter is a thermal parameter.

32. The system for the remote sensing of environmental parameters of claim 26 wherein the physical parameter is acceleration.

33. The system for the remote sensing of environmental parameters of claim 26 wherein the physical parameter is temperature.

34. The system for the remote sensing of environmental parameters of claim 1 wherein the sensed environmental parameter is electromagnetic radiation or optical photons (as with a CCD or Camera).

35. The system for the remote sensing of environmental parameters of claim 1 wherein more than one environmental parameter is sensed.

36. The system for the remote sensing of environmental parameters of claim 1 wherein more than one concentration or value of a single environmental parameter is sensed.

37. The system for the remote sensing of environmental parameters of claim 1 wherein more than one parameter is sensed on the same platform or chip or detector.

38. The system for the remote sensing of environmental parameters of claim 1 wherein the coupling is a thin server or embedded server

39. The system for the remote sensing of environmental parameters of claim 1 wherein the coupling is an embedded net-access chip.

40. The system for the remote sensing of environmental parameters of claim 1 wherein the coupling is a telephone modem.

41. The system for the remote sensing of environmental parameters of claim 1 wherein the coupling is a cable modem.

42. The system for the remote sensing of environmental parameters of claim 1 wherein the coupling is wireless.

43. The system for the remote sensing of environmental parameters of claim 1 wherein the coupling is an Ethernet connection.

44. The system for the remote sensing of environmental parameters of claim 1 wherein the communication network includes the Internet.

45. The system for the remote sensing of environmental parameters of claim 1 wherein the communication network includes an intranet.

46. The system for the remote sensing of environmental parameters of claim 1 wherein the communication network includes a LAN.

47. The system for the remote sensing of environmental parameters of claim 1 wherein the communication network includes straight communications path to a vehicle console.

48. The system for the remote sensing of environmental parameters of claim 1 wherein the communication network includes a WAN or Hyperlan (Ultra wideband network).

49. The system for the remote sensing of environmental parameters of claim 1 wherein the communication network includes dial up network.

50. The system for the remote sensing of environmental parameters of claim 1 wherein the communication network includes a wireless communication path.

51. The system for the remote sensing of environmental parameters of claim 1 wherein the processor further provides information to the remote location.

52. The system for the remote sensing of environmental parameters of claim 1 wherein the system further includes memory at the first location coupled to digital sensor.

53. The system for the remote sensing of environmental parameters of claim 1 wherein the system further includes a control system at the first location coupled to the digital sensor.

54. The system for the remote sensing of environmental parameters of claim 1 wherein the system further includes a clock at the first location coupled to the control system.

55. The system for the remote sensing of environmental parameters of claim 1 wherein the system further includes a neural network.

56. The system for the remote sensing of environmental parameters of claim 55 wherein the neural network is a distributed network.

57. A sensor assembly component for use in a system including at least one sensor assembly at a first location, the sensor assembly adapted to be coupled to and communicate over a network with at least one second location, the sensor assembly including:

a plurality of analog sensors, the sensors being disposed on a support substrate, the analog sensors providing signal outputs responsive to at least one stimulus to the sensor assembly,

coupling electronics for outputting the signal outputs to analog to digital converters,

analog to digital converters, the converters adapted to receive the signal outputs from the coupling electronics, and to provide a digital signal output corresponding to the signal outputs,

a processor, the processor being coupled to the outputs of the analog to digital converters, and being adapted to receive as input the digital signals output corresponding to the signal outputs, and

a network connection adapted to interface with the network and to provide communications to and receive communications from the network, including information relating to the signal outputs.

58. A system for sensing parameters at a plurality of remotely separated locations, the remotely separated locations being interconnected by a network, the system comprising:

a first sensor-node cluster, comprising:

a plurality of sensor assemblies,

at least one node,

the plurality of sensor assemblies adapted for communications with the node,

a second sensor-node cluster, comprising:

a plurality of second sensor assemblies, the second sensor assemblies being distinct from the sensor assemblies of the first sensor-node cluster,

at least one second node, the second node being distinct from the nodes of the first sensor-node cluster,

the plurality of second sensor assemblies adapted for communications with the second nodes of the second sensor-node cluster, and

a network coupled to the first sensor-node cluster and the second sensor-node cluster for communication there between.

59. A system for sensing parameters at a plurality of remotely separated locations, the remotely separated locations being interconnected by a network, the system comprising:

a first sensor-node cluster, comprising:

a plurality of sensor assemblies,

at least one node,

the plurality of sensor assemblies adapted for communications with the node,

a second sensor-node cluster, comprising:

a plurality of second sensor assemblies, the second sensor assemblies being distinct from the sensor assemblies of the first sensor-node cluster,

at least one second node, the second node being distinct from the nodes of the first sensor-node cluster,

the plurality of second sensor assemblies adapted for communications with the second nodes of the second sensor-node cluster,

a third node, the third node being distinct from the nodes of the first sensor-node cluster and the second sensor-node cluster, the third node being coupled to at least some of the sensor assemblies in the first sensor-node

cluster and some of the sensor assemblies in the second sensor node cluster, and

a network coupled to the first sensor-node cluster and the second sensor-node cluster for communication there between.

60. The system for sensing parameters at a plurality of remotely separated locations of claim 59, wherein the third node is connected to some, but not all, of the sensor assemblies in the first sensor-node cluster and the second sensor-node cluster.

61. A method for sensing a plurality of parameters at over 100 remote locations, each remote location including at least one sensor assembly, the sensor assemblies having nodes associated therewith, the method comprising the steps of:

sensing the parameters at the remote locations, the sensing generating data corresponding to the parameters,

storing the data at each of the said remote locations,

generating statistical data from the data,

checking for instructions from a node,

responding to the instruction in the event one has been received by the sensor assembly, or in the alternative, waiting for another command, and

sending the statistical data to the node at a predetermined time.

62. A system for sensing parameters at a large number of remote locations, comprising:

at least 10 sensor assemblies, each sensor assembly including:

a sensor including a digital output related to the parameter, and

a network connection adapted to provide the digital output to the network, and

a coupling to the network,

a network, and

a remote processor.

63. The system of claim 62 for sensing parameters at a large number of remote locations wherein the remote processor is a node.

64. The system of claim 62 for sensing parameters at a large number of remote locations wherein the remote processor is a end user.

65. The system of claim 62 for sensing parameters at a large number of remote locations wherein the coupling includes a wireless communication system.

66. The system of claim 62 for sensing parameters at a large number of remote locations wherein the coupling includes a wired communication system.

67. A computer program embodied on a computer-readable medium for controlling, processing and use of sensed data signals relating to environmental parameters comprising:

a sensor assembly source code segment comprising code for the receipt, and storage of signals corresponding to said data signals,

a network communication source code segment for communication of information from the sensor assembly to a network and from a network to the sensor assembly, and

a processor source code segment associated with a processor remote from said sensor assembly, and operatively coupled to the network.

68. The computer program embodied on a computer-readable medium of claim 67 wherein the processor source code segment resides on a node.

69. The computer program embodied on a computer-readable medium of claim 67 wherein the processor source code segment resides on an end user processor.

70. A computer data signal embodied in a carrier wave for controlling, processing and use of sensed data signals relating to environmental parameters comprising:

a sensor assembly source code segment comprising code for the receipt, and storage of signals corresponding to said data signals,

a network communication source code segment for communication of information from the sensor assembly to a network and from a network to the sensor assembly, and

a processor source code segment associated with a processor remote from said sensor assembly, and operatively coupled to the network.

71. The computer data signal embodied in a carrier wave of claim 70 wherein the processor source code segment resides on a node.

72. The computer data signal embodied in a carrier wave of claim 70 wherein the processor source code segment resides on an end user processor.

73. A method for the computer management of information from a plurality of physically separated sensors generating information comprising the steps of:

receiving at the computer information from a plurality of sensors,

processing the information in accordance with a program,

providing an output, and

charging a third party a fee for the management of the information.

74. The method for the computer management of information of claim 73 wherein the information is provided from the sensors to the computer at least in part via a global information network.

75. The method for the computer management of information of claim 74 wherein the global information network is the Internet.

76. The method for the computer management of information of claim 73 wherein the information comes at least in part from nodes.

77. The method for the computer management of information of claim 73 wherein the output consists at least in part of a report to the third party.

78. The method for the computer management of information of claim 73 wherein the output consists at least in part of information provided to a sensor.

79. The method for the computer management of information of claim 73 wherein the output consists at least in part of information for control of an actuator.

80. The method for the computer management of information of claim 73 wherein the program includes a data extraction step.

81. The method for the computer management of information of claim 73 wherein the program includes a data mining step.

82. The method for the computer management of information of claim 77 wherein the output consists at least in part of a report accessed via the Internet.

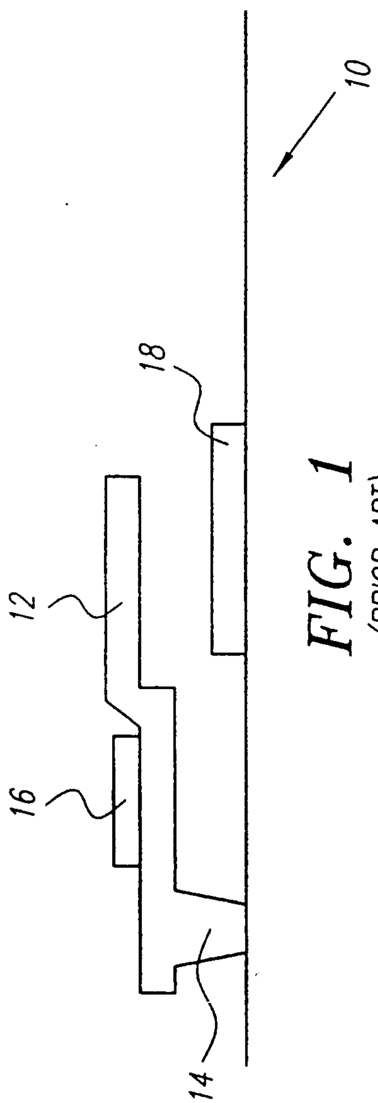


FIG. 1
(PRIOR ART)

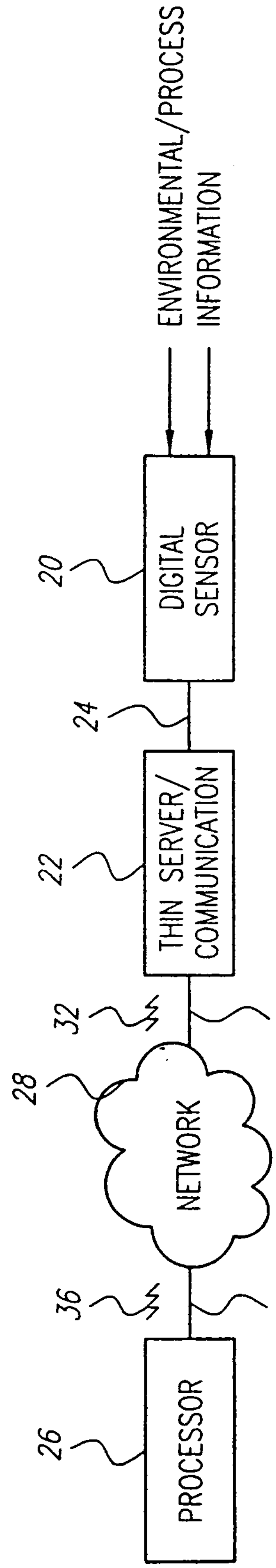


FIG. 2

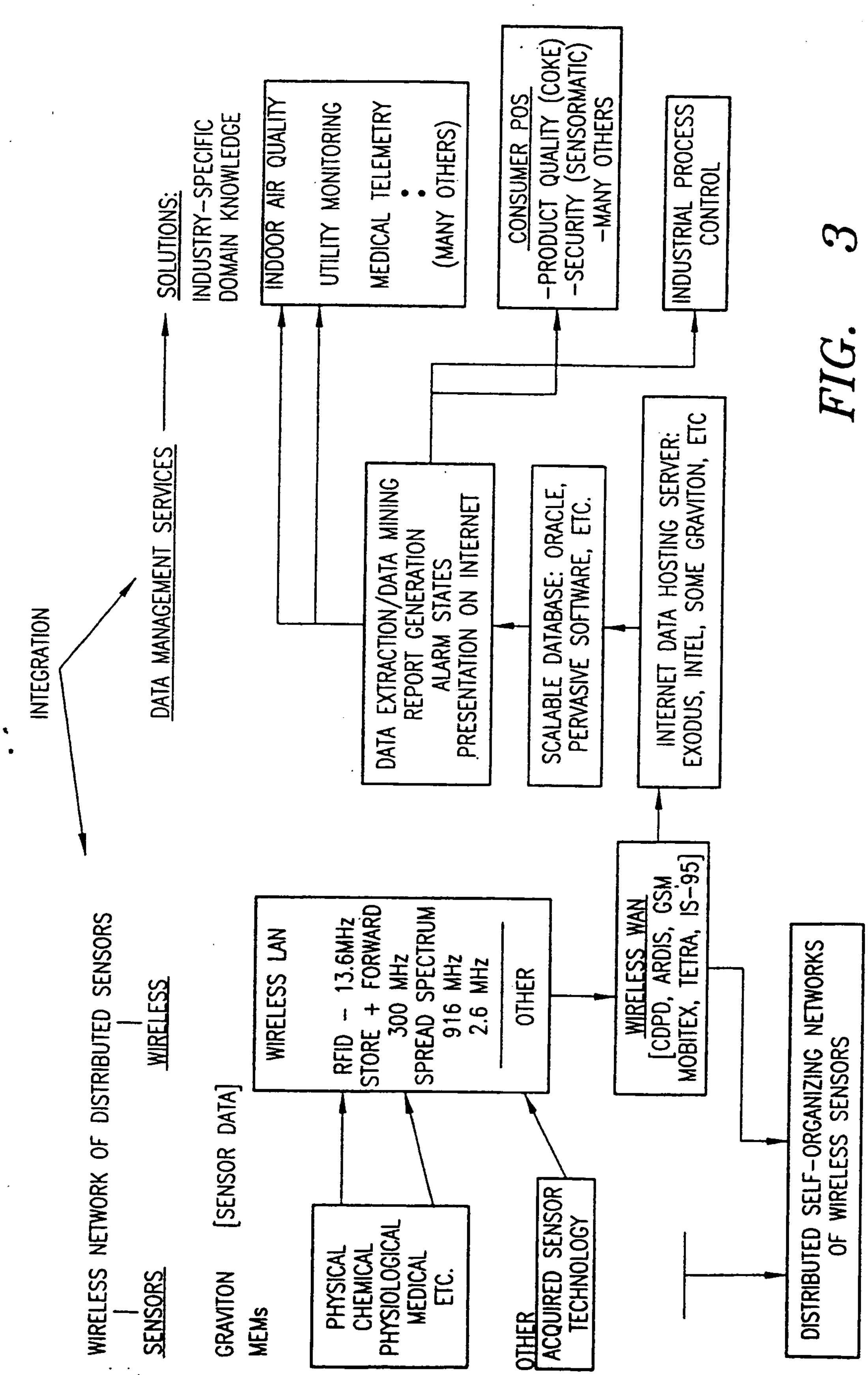
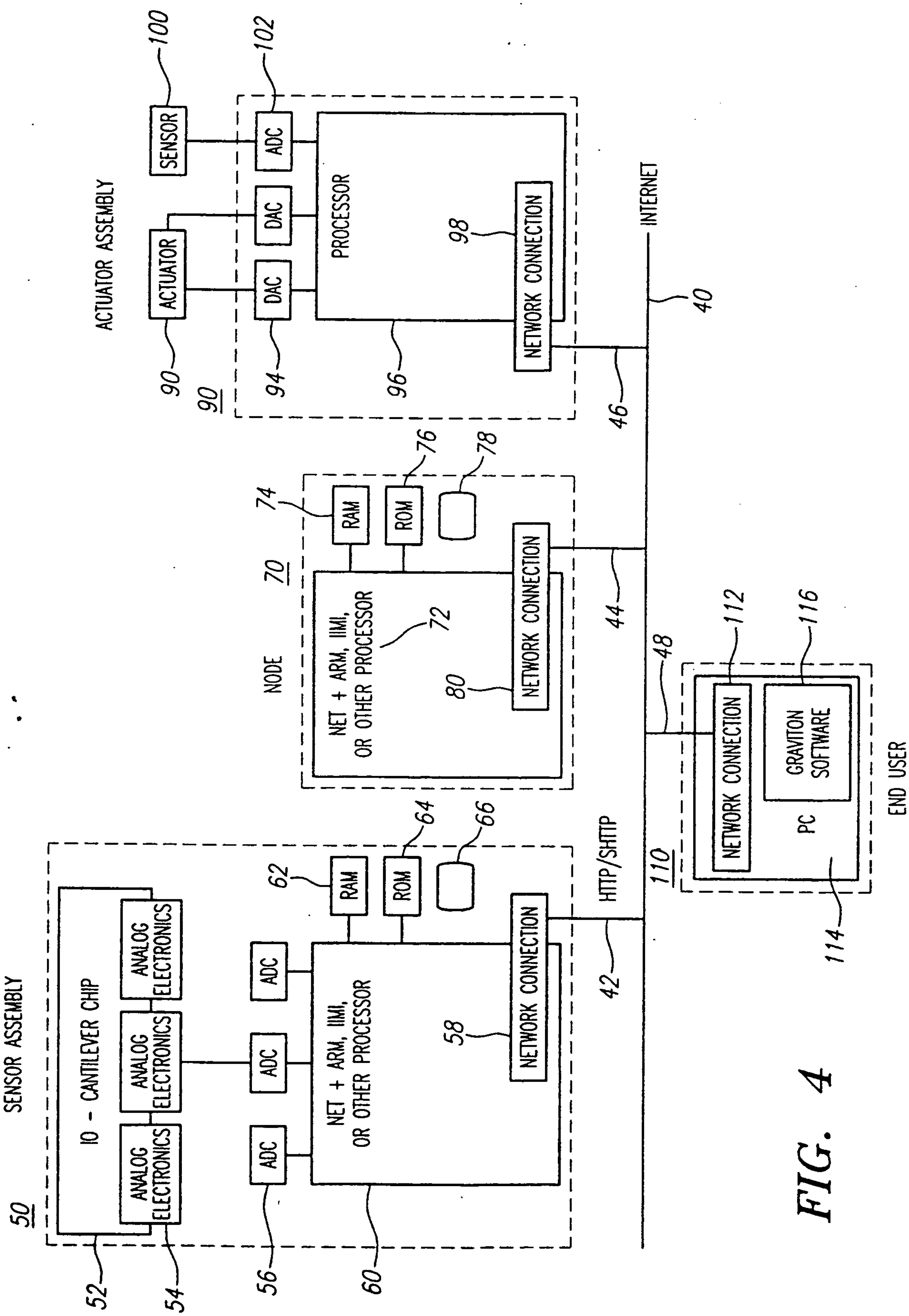

WIRELESS NETWORK OF DISTRIBUTED SENSORS
SENSORS
WIRELESS
GRAVITON
MEMs
[SENSOR DATA]
PHYSICAL
CHEMICAL
PHYSIOLOGICAL
MEDICAL
ETC.
OTHER
ACQUIRED SENSOR TECHNOLOGY
WIRELESS LAN
RFID - 13.6MHz
STORE + FORWARD
300 MHz
SPREAD SPECTRUM
916 MHz
2.6 MHz
OTHER
WIRELESS WAN
[CDPD, ARDIS, GSM
MOBITEX, TETRA, IS-95]
DISTRIBUTED SELF-ORGANIZING NETWORKS OF WIRELESS SENSORS
INTEGRATION
DATA MANAGEMENT SERVICES
SOLUTIONS:
INDUSTRY-SPECIFIC
DOMAIN KNOWLEDGE
DATA EXTRACTION/DATA MINING
REPORT GENERATION
ALARM STATES
PRESENTATION ON INTERNET
SCALABLE DATABASE: ORACLE,
PERVASIVE SOFTWARE, ETC.
INTERNET DATA HOSTING SERVER:
EXODUS, INTEL, SOME GRAVITON, ETC
INDOOR AIR QUALITY
UTILITY MONITORING
MEDICAL TELEMETRY
(MANY OTHERS)
CONSUMER POS
-PRODUCT QUALITY (COKE)
-SECURITY (SENSORMATIC)
-MANY OTHERS
INDUSTRIAL PROCESS CONTROL

FIG. 3


ACTUATOR ASSEMBLY
ACTUATOR
SENSOR
DAC
DAC
ADC
PROCESSOR
NETWORK CONNECTION
INTERNET
NODE
RAM
ROM
NET + ARM, IIMI, OR OTHER PROCESSOR
NETWORK CONNECTION
SENSOR ASSEMBLY
IO - CANTILEVER CHIP
ANALOG ELECTRONICS
ANALOG ELECTRONICS
ANALOG ELECTRONICS
ADC
ADC
ADC
RAM
ROM
NET + ARM, IIMI, OR OTHER PROCESSOR
NETWORK CONNECTION
HTTP/SHTTP
NETWORK CONNECTION
GRAVITON SOFTWARE
PC
END USER
40
42
44
46
48
50
52
54
56
58
60
62
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114
116

FIG. 4

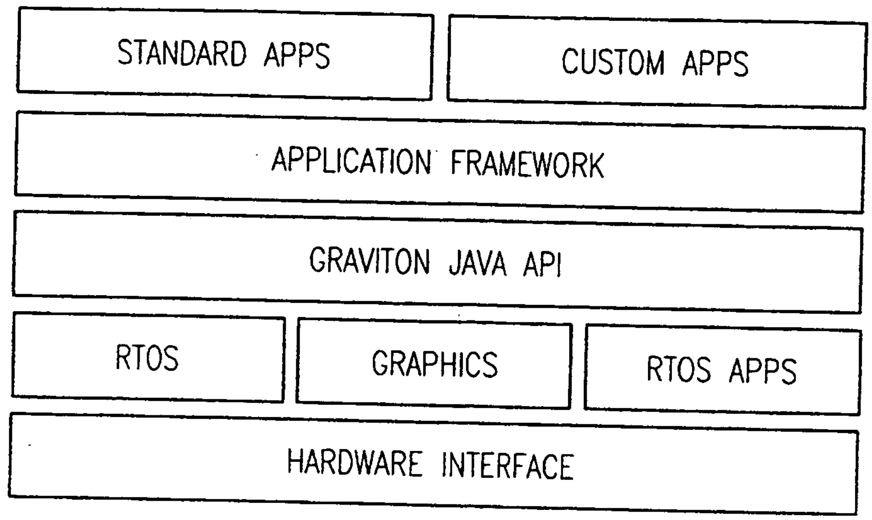
STANDARD APPS
CUSTOM APPS
APPLICATION FRAMEWORK
GRAVITON JAVA API
RTOS
GRAPHICS
RTOS APPS
HARDWARE INTERFACE

FIG. 5

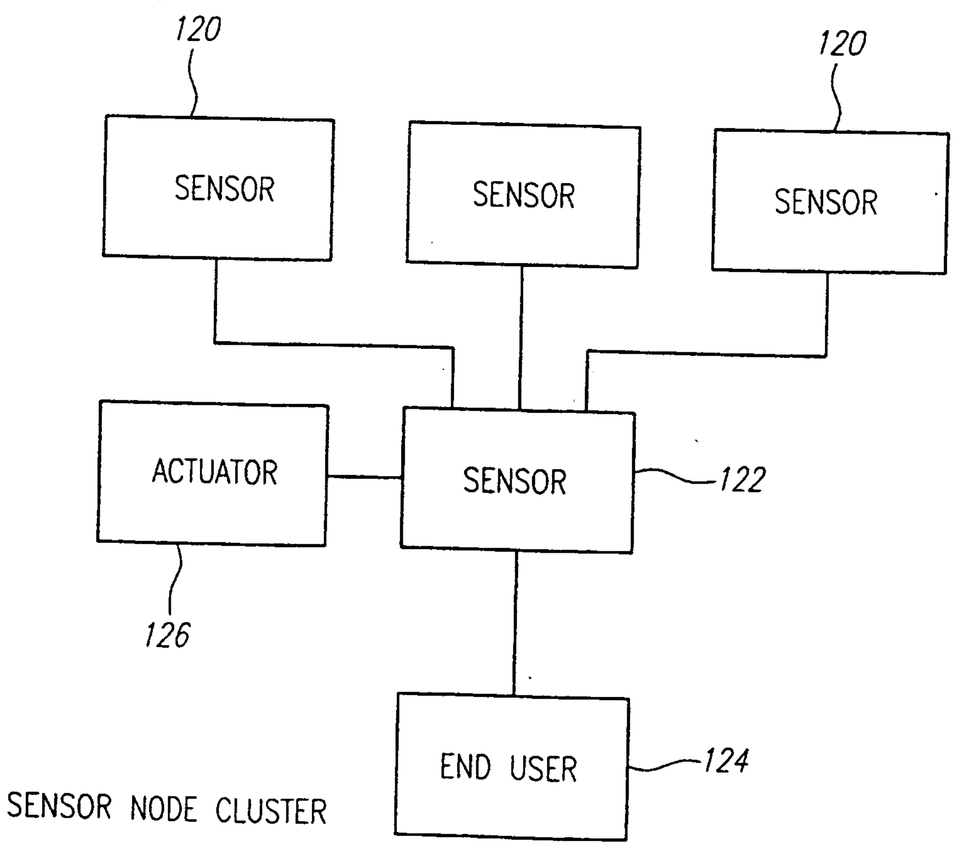
120
120
SENSOR
SENSOR
SENSOR
ACTUATOR
SENSOR
122
126
END USER
124
SENSOR NODE CLUSTER

FIG. 6

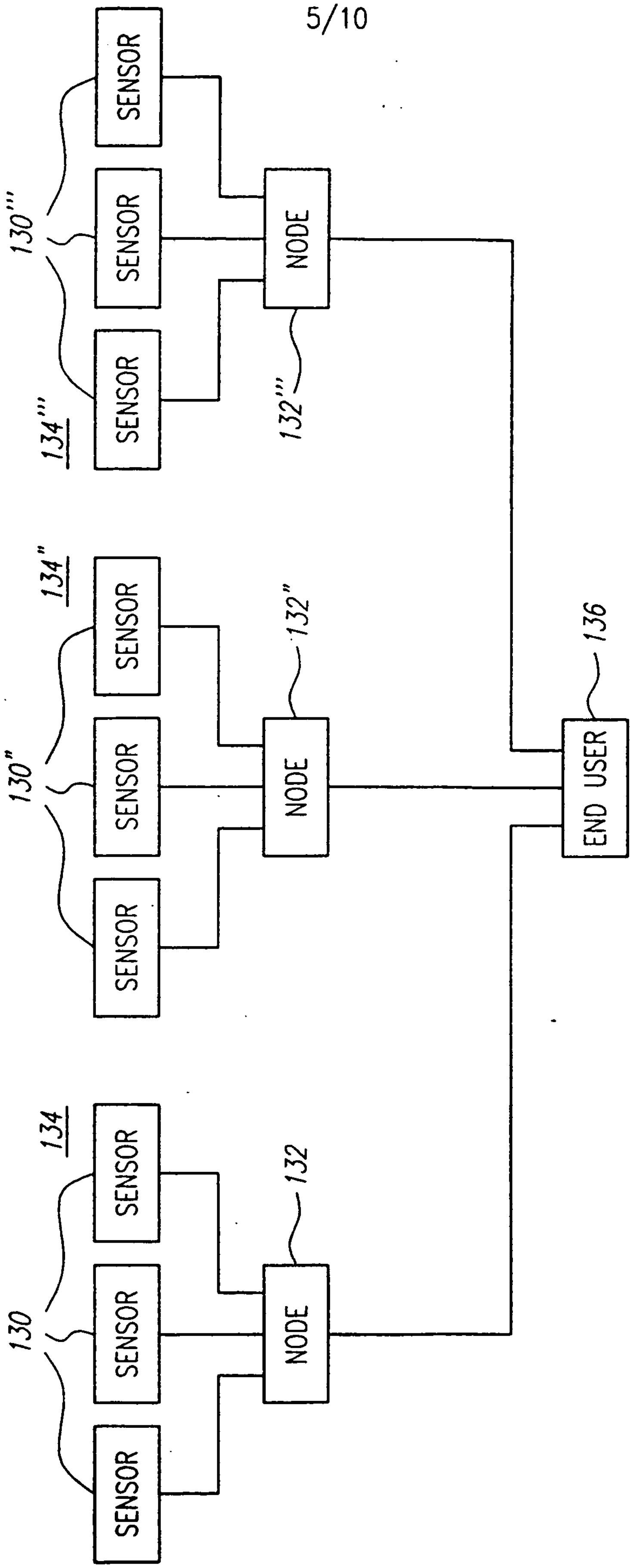
SENSOR
SENSOR
SENSOR
NODE
130'''
134'''
132'''
SENSOR
SENSOR
SENSOR
NODE
130"
134"
132"
SENSOR
SENSOR
SENSOR
NODE
130
134
132
END USER
136

FIG. 7

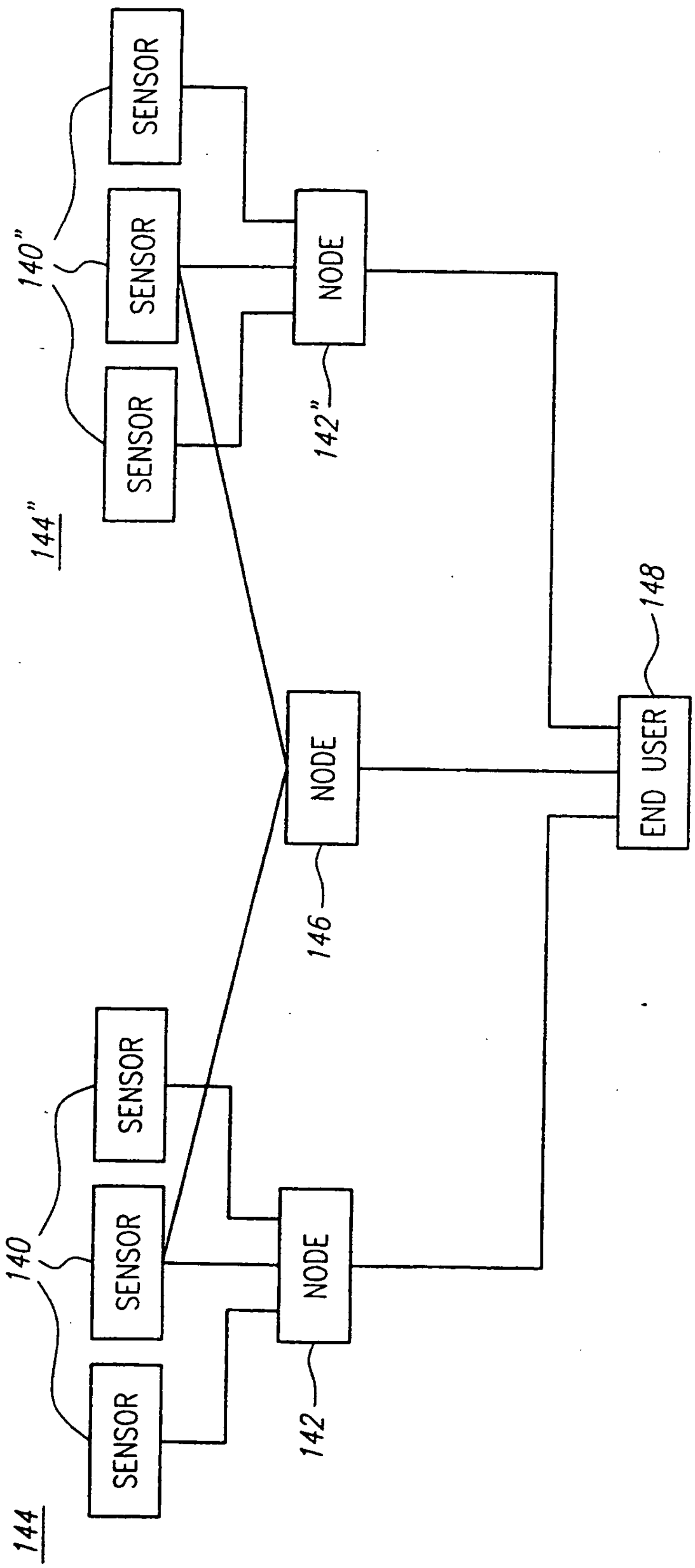
144"
140"
SENSOR
SENSOR
SENSOR
NODE
142"
NODE
146
END USER
148
144
140
SENSOR
SENSOR
SENSOR
NODE
142

FIG. 8

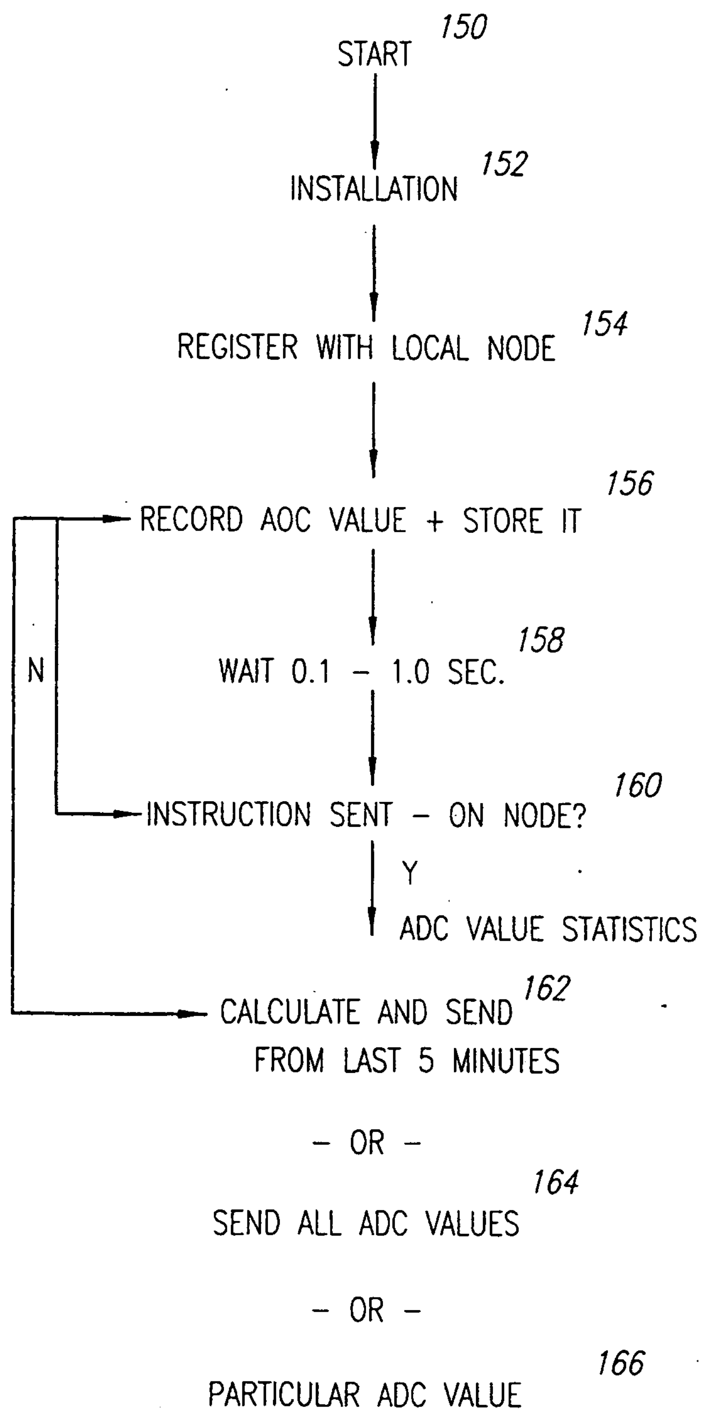
START 150
INSTALLATION 152
REGISTER WITH LOCAL NODE 154
RECORD AOC VALUE + STORE IT 156
N
WAIT 0.1 - 1.0 SEC. 158
INSTRUCTION SENT - ON NODE? 160
Y
ADC VALUE STATISTICS
CALCULATE AND SEND 162
FROM LAST 5 MINUTES
- OR -
SEND ALL ADC VALUES 164
- OR -
PARTICULAR ADC VALUE 166

FIG. 9

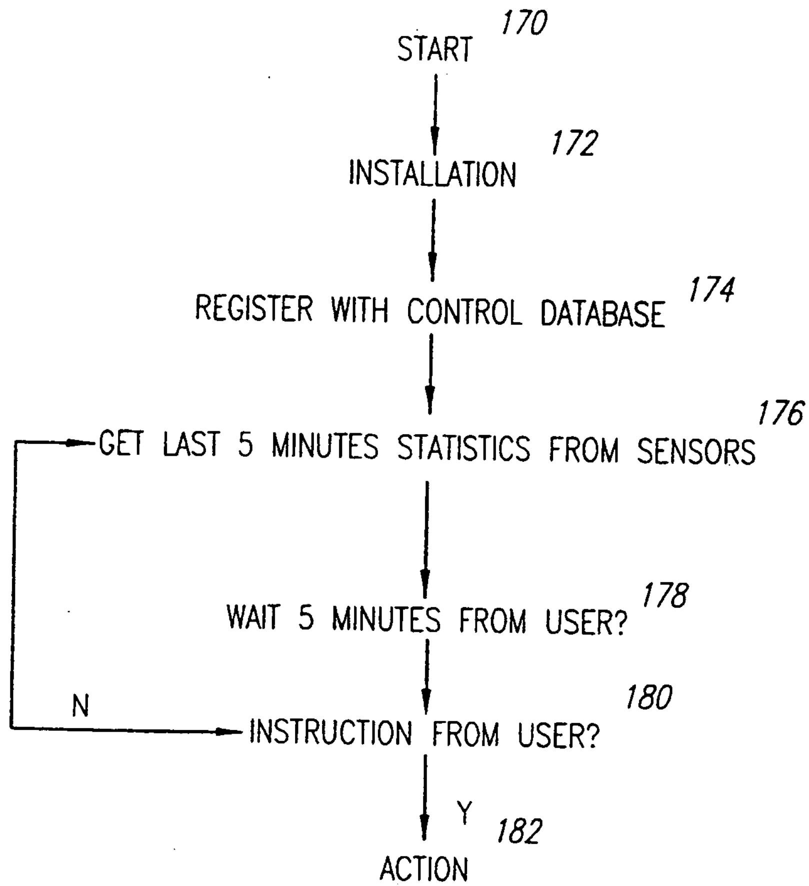
START 170
INSTALLATION 172
REGISTER WITH CONTROL DATABASE 174
GET LAST 5 MINUTES STATISTICS FROM SENSORS 176
WAIT 5 MINUTES FROM USER? 178
N
INSTRUCTION FROM USER? 180
Y
182
ACTION

FIG. 10

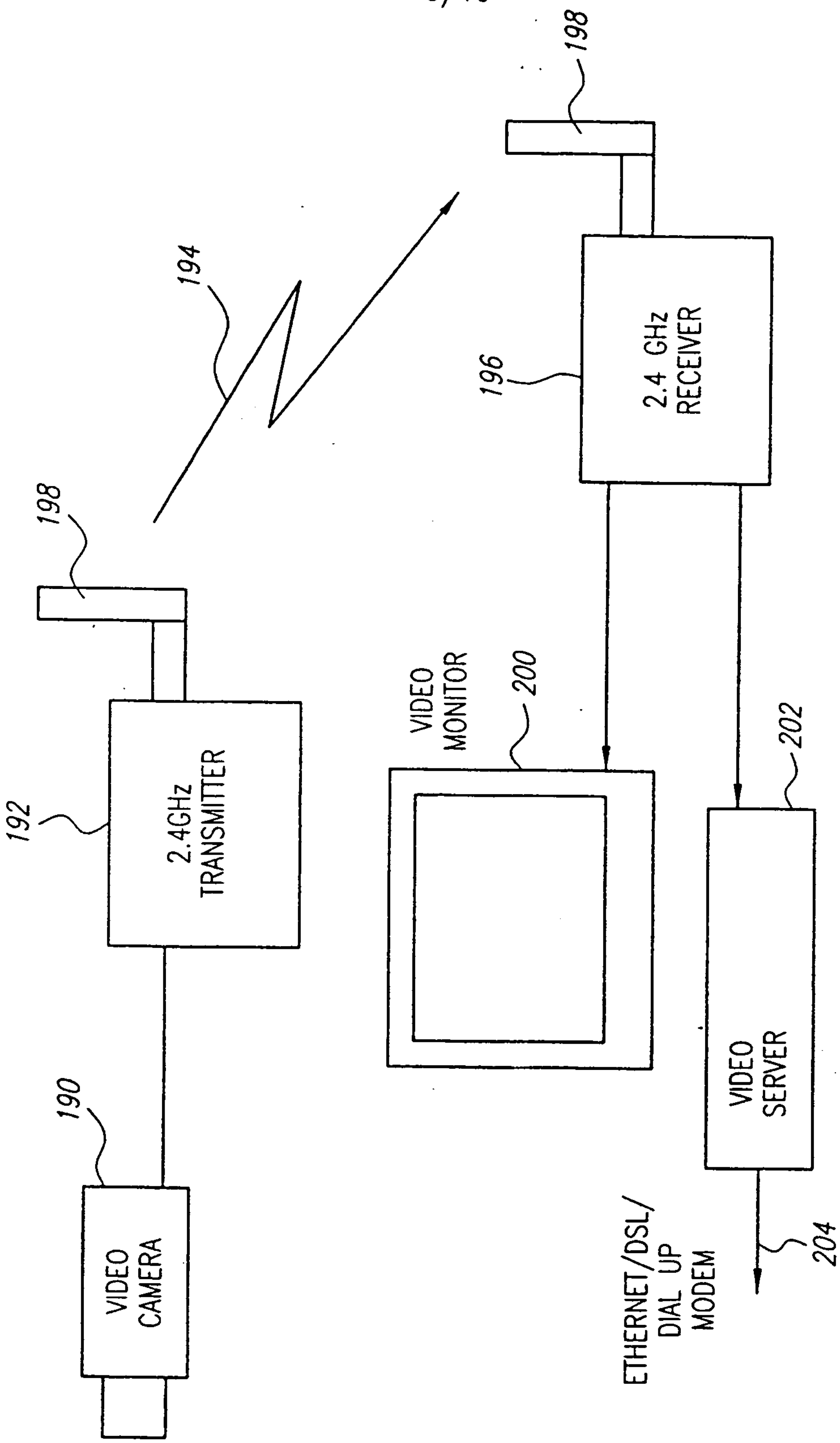
198
194
2.4 GHz RECEIVER
196
198
2.4GHz TRANSMITTER
192
VIDEO MONITOR
200
202
VIDEO SERVER
190
VIDEO CAMERA
ETHERNET/DSL/ DIAL UP MODEM
204

FIG. 11

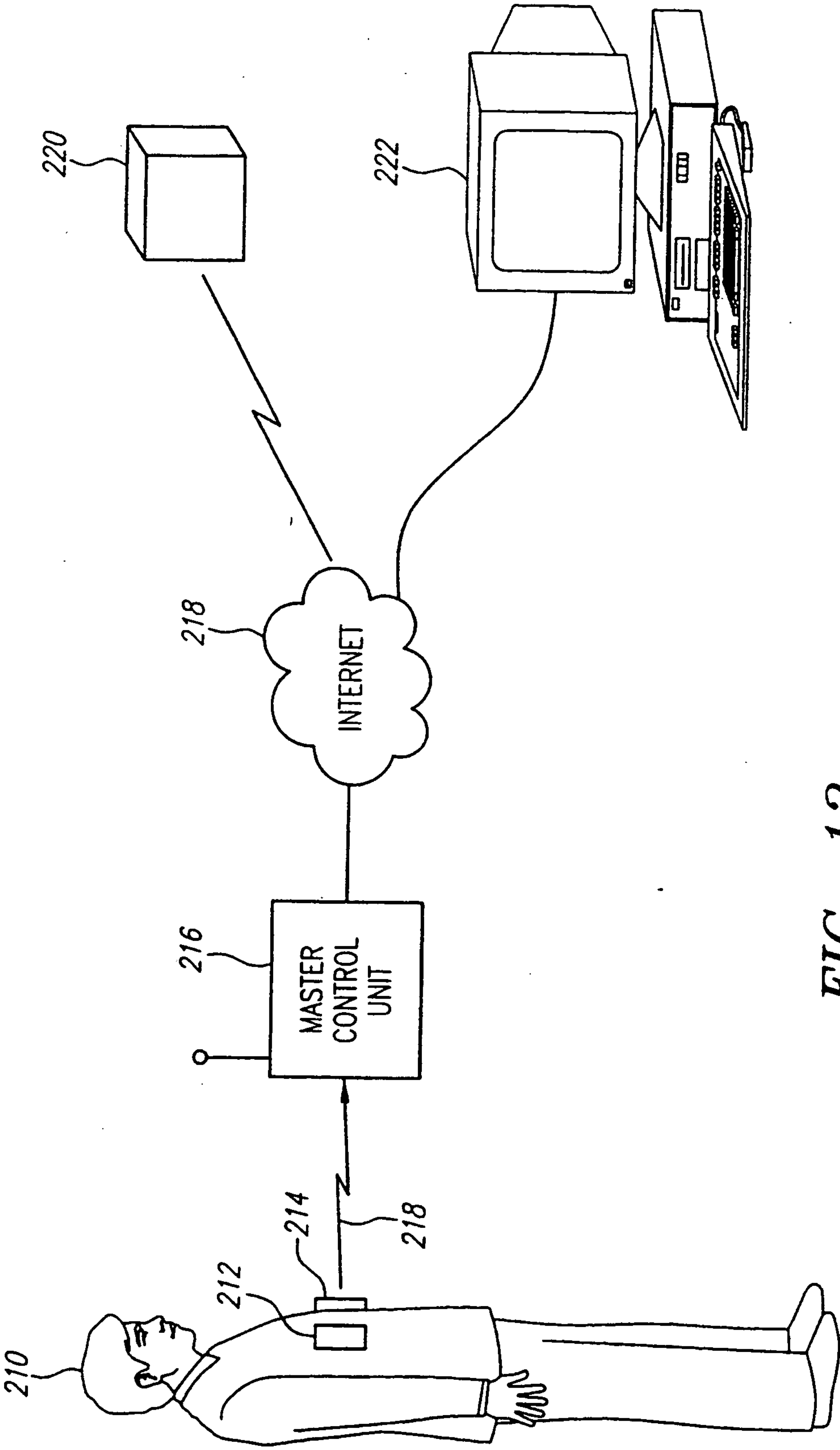

FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/06312

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :G08B 23/00
US CL :340/517,506,511,524,531,533,539,825.06,825.36
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 340/517,506,511,524,531,533,539,825.06,825.36

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,400,246 A (WILSON et al) 21 March 1995, col 10, lines 15 et seq.	1-82

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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Date of the actual completion of the international search	Date of mailing of the international search report
03 JUNE 2000	31 JUL 2000

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